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NON-CONVENTIONAL FEED RESOURCES IN ASIA AND THE PACIFIC

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NON-CONVENTIONAL FEED RESOURCES IN ASIA AND THE PACIFIC

SECOND EDITION

by
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F O R E W O R D

The inadequate supply of feed, both quantitatively and qualitatively is one of the principal limiting factors to the efficient animal production in Asia and the Pacific Region. FAO has in this context been giving attention to the non-conventional feed resources (NCFR). In 1976, the Expert Consultation on New Feed Resources convened by FAO highlighted the great potential of such feeds in feeding systems for farm animals in the different regions of the world. Later, the FAO Regional Animal Production and Health Commission for Asia, the Far East and the South-West Pacific (APHCA) organized in January 1980, the International Workshop on Studies on Feeds and Feeding of Livestock and Poultry in Manila, Philippines. The workshop observed that unconventional feedstuffs were not being fully utilized due to scanty or inadequate information on these feeds. As a follow-up to this workshop, the FAO Regional Office for Asia and the Pacific (RAPA), organized an Expert Consultation on Regional Cooperation in Production, Utilization and Trade of Feedstuffs in the Region. This consultation observed that feed compounding and utilization was heavily dependent on cereals and other imported feedstuffs. They had not been replaced by the many available NCFR. Little effort has been made to tap the potential of these NCFRs.

In order to fill the gap in the information on this subject, Dr. C. Devendra, Principal Research Officer, Malaysian Agricultural Research and Development Institute (MARDI), Serdang, Selangor, Malaysia, was requested to undertake a thorough review of literature on the availability and utilization of non-conventional feed resources in this region. His findings were published in 1981 as FAO/APHCA Publication entitled "Non-conventional Feed Resources in Asia and the Far East." There was a big demand for it and by the end of 1984 all the copies were distributed. It was therefore decided to update the information and publish an updated and revised edition. It is hoped that this publication will help in replacing the cereals required for human food by the non-conventional feed resources in the formulation of compound animal feeds and their utilization.

1. INTRODUCTION

1.1 Animal populations in Asia and the Pacific

Table I presents a summary of the population of individual animals in Asia and the Pacific according to FAO (1984). It also presents an indication of the magnitude of these individual populations relative to the total world populations.

It can be seen that the region possesses a very large percentage of the world's population of buffaloes (95.9%), more than half the duck population (67.3%), 45.5% of the population of goats, 45.4% of the pig population and 27.1% of cattle. The chicken and sheep populations were 28.1 and 17.1% respectively of the total world population of each of these animal classes.

Clearly, the ruminant populations are numerically more important than the non-ruminants. In the context of the availability of vast quantities of non-conventional feedstuffs resources (NCFR), the majority of which are poor quality roughages with a high fibre content, the potential role of ruminants in converting these feedstuffs to useful edible animal product for man assumes one of considerable importance in the future. Ruminants therefore have a particularly important function to play in the utilization of these feed materials and efficient food production.

1.2 Manufacture of animal feedstuffs

The manufacture of animal feedstuffs in the Region varies from country to country both in the quantity and the type of feedstuffs produced. The manufacture of these is a complex process involving the procurement of raw feed ingredients nutritive value and variability, storage prior to processing, mixing the ingredients in the right proportions in least cost formulations, and achieving the final objective of a balanced diet at low and competitive costs that can promote good animal performance. However, the situation is confronted seriously by a variety of problems, notably reliability of a continuous supply of raw materials variable quality and rising cost of these materials.

Possibly the most pressing problem however is the spiralling cost of raw materials and the dependence on these feedstuffs to sustain animal production. In general, most countries in the Region are not self-sufficient in energy sources such as cereals and cassava. Some countries like Malaysia on the other hand, are very dependent on the import of maize for feeding pigs and poultry to the tune of about 580,000 tonnes of maize valued at about US$85 millions are imported annually. By 1990, the projected cost of the imported maize and rice meal is estimated to be about US$323 million.

While the utilization of imported maize by individual countries is variable, the import of fish meal and mineral-vitamin supplements is common to all countries. This is justified because the local availability of both is low and in addition, local fish meal is usually of poor quality. It is likely that this trend of importation will continue.

TABLE 1

THE POPULATION OF ANIMALS IN ASIA AND THE PACIFIC

(FAO, 1984, 1000 heads)

COUNTRY	CATTLE	BUFFALOES	PIGS	SHEEP	GOATS	CHICKENS	DUCKS
Australia	21,846	--	2,500	140,649	230	46	--
Bangladesh	36,300	1,720	--	1,095	12,000	75	21
Bhutan	315	28	74	43	45	--	--
Burma	9,550	2,100	2,750	400	1,000	32	6
China	58,560	19,144	298,536	98,916	68,035	1,245	12
Fiji	158	--	29	--	55	1	--
India	182,160	64,000	8,650	40,890	80,800	160	--
Indonesia	6,800	2,391	3,620	4,790	7,910	133	17
Japan	4,664	--	10,423	22	57	300	--
Kampuchea DM	1,200	470	750	1	--	--	2
Korea DPR	1,050	--	2,550	340	--	--	--
Korea REP	2,215	--	3,649	6	350	49	--
Laos	500	915	1,350	--	58	--	--
Malaysia	575	255	2,050	69	335	55	--
Mongolia	2,400	--	40	15,100	4,900	--	--
Nepal	7,000	4,530	370	2,500	2,680	25	--
New Zealand	7,330	--	450	69,700	90	--	--
Pakistan	16,350	12,800	--	24,000	28,700	78	2
Papua New Guinea	134	--	1,460	2	16	4	--
Philippines	1,920	2,900	7,779	30	1,850	55	--
Samoa	26	--	61	--	--	--	--
Sri Lanka	1,700	915	77	29	520	6	--
Thailand	4,620	6,150	4,150	22	30	75	15
Tonga	11	--	101	--	17	--	--
Vanuatu	100	--	71	--	8	--	--
Vietnam	2,169	2,500	11,180	18	200	53	29
Total	369,653	120,818	362,668	398,621	209,885	2,398	104
World population	1,265,850	125,917	778,143	1,130,141	470,145	7,662	159
As % of the total world population	29.2	96.0	46.6	35.3	44.6	31.3	65.4

On the other hand, there are some countries like Sri Lanka which produce annually quite considerable supplies of coconut cake, wheat bran, rice bran, sesame cake and smaller quantities of rubber seed meal and kapok seed meal. The cost of these feeds is considerably lower than of imported ones, and for this reason alone, considerable reliance is being attached to use these feeds instead of imported feestuffs.

In considering the use of both imported and locally available feedstuffs, and potential possibilities for increasing the use of NCFR, one valuable index is the extent to which feedstuffs of local or within-country origin are currently being used. This index is also valuable from the standpoint of possibilities related to decreased cost of feeding or the production of alternative feeds incorporating maximum amounts of non-conventional feeds that can be marketed at competitive costs.

Table 2 presents a summary of this position in selected countries. These figures have been derived from an analysis of imports and exports of animal feeds, pattern of manufacture of feedstuffs for animals and discussions with feed millers in the countries. It is emphasized that the figures are by no means exact, and are only meant to give a guide to the current status.

2. NON-CONVENTIONAL FEED RESOURCES (NCFR)

2.1 Background

In animal production systems, it has been traditional to feed conventional feeds notably cereals, oil cakes and meals to both ruminants and non-ruminants. This tendency has been mainly motivated by the presence of developed technology that is both applicable and viable. in essentially temperate environments. Additionally, this developed technology is often advocated in text books and recommendations in the belief that its proven worth is also applicable to tropical situations. This is associated with the point that there has been little demonstration of alternative technology developed in, and suitable to, specific circumstances in the tropical regions.

It is doubtful whether specialized technologies on feeding systems developed in the temperate countries are entirely appropriate to the needs of the developing countries in the tropics. A major disadvantage of the acceptance of technology on feeding systems that are primarily suited to temperate conditions is that it is often irrelevant to the tropics and also unrealistic. It also effectively increases the dependence on traditional feeds without relieving feed shortages, thus contributing to the mounting pressure on world feed resources.

In international markets, and notably due to relatively strong demand and supply management measures in the United States, prices of feed grains and feed proteins have been increasing. This is reflected for example,

TABLE 2

APPROXIMATE PERCENTAGE OF LOCAL FEEDSTUFFS USED BY FEED MANUFACTURES IN SELECTED COUNTRIES IN ASIA AND THE PACIFIC

Country	% utilization of feedstuffs of local origin in the manufacture of feed for animal
Bangladesh	90
India	95
Indonesia	70 - 75
Malaysia	40 - 50
Pakistan	95
Philippines	80
Sri Lanka	90
Thailand	95

in an increase in the composite feedstuffs price index in the United States, and also the FAO vegetable and oil cake index. Additionally, the price of most livestock products, and particularly that of beef and veal rose faster than that of concentrate feeds in most developing countries.

With specific reference to species and types of livestock, it is also essential to keep in perspective the characteristics and peculiarities of tropical feeds, their extreme variability, utilization and nutritional constraints that restrict high performance. Many of the tropical feeds are from quality roughage materials, mainly crop residues which are dominated by cell wall materials. These materials do not contain starch but more often sugar (eg. molasses and fruit wastes) and the protein content is negligible. Thus, their utilization must take cognisance of their capacity to release dietary energy and nitrogen. In respect of the former, this also necessitates consideration of alternative processing techniques which for example with alkalis, enables solubilization of the hemicellulose fractions plus increased susceptibility of the cell wall to microbial degradation. Much will depend of course on whether the added benefits in terms of animal response is significantly higher than the associated costs of processing and or treatment (Devendra, 1984).

These considerations clearly emphasise the need to look beyond the traditional feed resources available so as to alleviate the demand for animal feeds, and also sustain animal production in the countries of Asia, Far East and the Pacific Region (hereafter referred to as the Region). A further justification for this approach is that in many countries in the Region, the imbalance between the total animal resources and feed supplies is so critical that the latter is often a major limiting factor in production. Notable in this regard are India and Pakistan. In India, the National Commission on Agriculture (1976), Government of India, has reported that there is a shortage of 44% of concentrates, 44% dry fodders and 38% green fodders for meeting the nutritional requirements of livestock. (Table 3).

The report also indicated that only 70% of the digestible crude protein (DCP) requirement of dairy animals, 50% of the requirement of dry animals, 40% of the requirement of adult cattle and about 20% of that of young cattle were being met from the available feeds. By the year 2000, there will be a shortage of all categories of feeds. Likewise in Pakistan, although 28.8 million tons of crop residues produce 14.2 million tons of total digestible nutrient (TDN), and 1.4 million tons of crude protein, there is still a deficit of 49% energy and 42% digestible crude protein (DCP) to feed livestock. In China, it is envisaged that a doubling of increased animal protein consumption by the turn of the centry will involve increased use of NCFR (Xiong, 1983). Probably because of this, least cost rations based on non-traditional feed resources meet 60-80% of the feed requirements of service-intensively fed ruminants (dairy, beef and lamb finishing), and up to 98% of extensively reared ruminants in Pakistan. It has been estimated in this connection, that at least 40% reduction in feed cost has been achieved by using non-traditional feeds in comparison to nutritionally equivalent rations using traditional feeds. (Shah and Mueller, 1983).

TABLE 3

FEEDS AND FOOD AVAILABILITY AND REQUIREMENTS IN INDIA (1973-2000, 10^6mt)
(National Commission in Agriculture, 1976)

	Concentrates		Dry fodders		Green fodders	
	1973	2000	1973	2000	1973	2000
AVAILABILITY	11.0	77.0	309.0	356.0	214.0	575.0
REQUIREMENTS						
Buffaloes	6.3	13.2	84.9	88.0	160.5	454.6
Cattle	10.8	45.6	253.0	269.0	242.0	575.0
Other	2.4	24.0	9.5	14.6	--	135.5
Total	19.5	82.8	347.0	373.0	343.4	594.8
Feed shortage	44.0	7.0	7.0	11.0	38.4	3.0

More recently, Verma (1983) analyzed the feed resource base in Asia in terms of area under pasture and fodder crops, quantities of available feed grains, oil cakes and agricultural by-products, the number of livestock necessary to provide the products and the services required, and has reported a quantitative and qualitative insufficiency of feeds in relation to the animals requirement for growth, reproduction and production.

The justification for increasing effective utilization of the feed resources in general, and non-conventional feed resources (NCFR) in particular, is associated with inadequate supplies and rising feed costs. This is favoured by the emphasis on crop production in Asian agriculture, with the simultaneous production of abundant and varied by-products, which together constitute an important wide variety of feed resources for feeding farm animals.

Several countries in the Region have expressed concern over the limited feed supplies, the increasing cost of imported feeds and the need to increase the use of NCFR. Many of these countries are now giving attention to NCFR as potentially valuable feeds and particularly to increase research and development effort that can increase their utilization and improve the efficiency of animal production.

The emphasis on crop production and the concurrent processing of some of the products result in effluents which cause serious pollution problems, eg. pineapple canning wastes, palm oil processing wastes, rubber processing wastes, slaughter house wastes and distillery wastes. Serious efforts should therefore be made to find effective and economic uses for these residues and wastes, without detriment to the environment.

Given these considerations, it is clear that a detailed assessment of these feed resources is timely and realistic. Timely because dwindling feed resources necessitates effective utilization of alternative or new feeds, and unrealistic because accelerating the production of animal protein supplies from the animal resources must be economic. The purpose of this report is to describe the nature of NCFR, production, extent of supply, nutritive value, current utilization, technical, biological and economic feasibility of utilizing these feeds in effective feeding systems for ruminant and non-ruminant animals in the Region. The value of some of the NCFR in the Region has previously been reviewed (Devendra, 1976a).

2.2 Definition

The non-conventional feed resources (NCFR) refer to all those feeds that have not been traditionally used in animal feeding and or are not normally used in commercially produced rations for livestock.

Defined in this manner the NCFR embrace a wide diversity of feeds that are typical of, and abundant in, the Region. A feature about these feeds is that whereas the traditional feeds of crop origin tend to be mainly from annual crops, the NCFR include commonly, a variety of feeds from perennial crops and feeds of animal and industrial origin. In this sense, the NCFR could really be more appropriately termed "new feeds", and this term is in fact being increasingly used.

Thus, the term NCFR has been frequently used to describe such new sources of feedstuffs as palm oil mill effluent and palm press fibre (oil palm by-products), single cell proteins, and feed material derived from agro-industrial by-products of plant and animal origin, poor-quality cellulosic roughages from farm residues such as stubbles, haulms, vines and from other agro-industrial by-products such as slaughter-house by-products and those from the processing of sugar, cereal grains, citrus fruits and vegetables from the processing of food for human consumption. This list can be extended by derivatives from chemical or microbial processes, as in the production of single cell proteins.

It is not easy however to draw a distinct demarcation between traditional feeds and NCFR. This is because in some countries such as India and Pakistan, what may now be classified NCFR may in fact be traditionally to the extent that it may have been fed for a long time. A case in point concerns wheat straw which is very widely used in both these countries. Additionally, the availability of NCFR, especially of plant origin, is dependent to a large extent on type of crops being cultivated, and the prevalent degree of application of the crop technology.

2.3 Characteristics

The NCFR have a number of characteristics that are worth documenting and to keep in perspective:

a) They are the end products of production and consumption that have not been used, recycled or salvaged.

b) They are mainly organic and can be in a solid, slurry or liquid form.

c) Their economic value is often less than the cost of their collection and transformation for use, and consequently, they are discharged as wastes.

d) The feed crops which generate valuable NCFR are excellent sources of fermentable carbohydrates eg. cassava and sweet potato and this is an advantage to ruminants because of their ability to utilize inorganic nitrogen.

e) Fruit wastes such as banana rejects and pineapple pulp by comparison have sugars which are energetically very beneficial.

f) Concerning the feeds of crop origin, the majority are bulky poor-quality cellulosic roughages with a high crude fibre and low nitrogen contents, suitable for feeding to ruminants.

g) Some of the feeds have deleterious effects on animals, and not enough is known about the nature of the active principles and ways of alleviating the effects.

h) They have considerable potential as feed materials, and for some, their value can be increased if there were economically justifiable technological means for converting them into some usable products.

i) More information is required on chemical composition, nutritive value, toxic factors and value in feeding systems.

The generation of NCFR, essentially from agriculture and various agro-based industries is a function of many factors. The quantity and quality of the materials produced is dependent upon prevailing agro-climatic conditions and cropping patterns, type of raw materials, the production process, the production rate, the type of inputs used, the regulations affecting product quality use, and the constraints imposed upon residual discharge.

Many of the NCFR are currently designated as wastes, and this is an inaccurate description. They are wastes to the extent that they have not been shown to have an economic value so that if these wastes can be utilized and converted by animals into valuable products for human benefit, they then become new feed materials of importance. Additionally, they can alleviate the existing limited feed resources. Recycling, reprocessing and utilization of all, or a portion of the wastes, offers the possibility of returning these to beneficial use, as opposed to the traditional methods of disposal and relocation of the same residues. The demonstration of potential value can thus make many of these wastes, new feeds of value and importance.

2.4 Availability

It is useful to establish the total availability of the NCFR in the Region. This has been done by multiplying total yield from individual crops by the extraction rate.

i) Extraction rates

The extraction rates that have been applied are given in Tables 4 and 5, based on field results of the by-products generated. Table 4 gives the extraction rates of major by-products, and these have been sub-divided from convenience, into field crops and tree crops. The field crops include cereals, root crops and grain legumes, and include such examples as cassava, castor, cotton, groundnuts, linseed, maize, sesame, soyabean, sugarcane and wheat. The tree crops include cocoa, coconuts, rubber and sago. Not all of these are however, non-conventional, and Tables 4 and 5 indicate these.

In addition to these, Table 5 presents the extraction rates of other non-conventional feedstuffs that are notably found in India and Pakistan.

ii) Quantity available

Using published information on the land area and total yield of individual crops (FAO, 1982), the availability of individual crop by-products have been calculated (Tables 6 and 7). It is apparent that from field, plantation and tree crops alone, the total availability of by-products is approximately 432 million tonnes. Of this total, it is estimated that about 190 millions or 44.0% are non-conventional which represents an enormous reservoir of NCFR.

It is stressed however, that the generation of NCFR is very much higher than these figures suggest, as Tables 6 and 7 do not include the production from a variety of other field crops (Table 5) statistics about which are not available in the FAO data. Additionally, there are also residues and wastes from animal sources and the processing of food for human consumption which have not been included. Finally, there also exist an abundant variety and supply of tree fodders that constitute valuable feeds especially for goats in the Region.

It is of interest to note from the data in Tables 6 and 7 that approximately 80% of the NCFR in field crops and 93% of the feeds in tree crops cultivation are principally suited for feeding ruminants. The utilization of these feeds by ruminants thus represents a most important function of the ruminant animals in the Asian and Pacific Region. These animals may at the present time be making the most efficient use of these feeds.

TABLE 4

MAJOR BY-PRODUCT FEEDS FROM TREE AND FIELD CROPS, WITH APPROXIMATE EXTRACTION RATES IN ASIA AND THE FAR EAST (Devendra, 1976a)

Crop	By-product feed	Approximate extraction rate (%)
1. Tree Crops		
Cocoa (*Theobroma cocoa*)	Cocoa bean waste	5 - 10
	Cocoa pod husks	70
Coconuts (*Cocos nucifera L.*)	Coconut meal	35 - 40
Oil Palm (*Elaeis guineensis*)	Oil palm sludge (dry)	2
	Palm press fibre	12
	Palm kernel meal	2
Rubber (*Hevea brasiliensis*)	Rubber seed meal	55 - 60
Sago (*Metroxylon sago*)	Sago refuse	55
2. Field Crops		
Castor (*Ricinus communis L.*)	Castor meal	45 - 50
Cotton (*Grossypium spp*)	Cotton seed meal	40 - 45
Maize (*Zea mays*)	Maize bran	8 - 10
	Maize germ meal	16 - 18
Rice (*Dryza sativa*)	Broken rice	4 - 5
	Rice bran	10
	Rice husk	15 - 17
	Rice straw	100*
Sugarcane (*Saccharum officinarum*)	Bagasse	12 - 15
	Green tops	15 - 20
	Molasses	3 - 4
Cassava (*Manihot esculenta Crantz*)	Tapioca waste	55 - 59
Wheat (*Triticum aestivum L.*)	Wheat bran	10
	Wheat straw	100*

* Implies equivalent weight to the yield of grains.

TABLE 5

MINOR BY-PRODUCT FEEDS FROM VARIOUS SOURCES, WITH APPROXIMATE EXTRACTION RATES IN ASIA AND THE FAR EAST

(Devendra and Raghavan, 1978)

Crop	By-product feed	Approximate extraction rate (%)
1. Plants		
1. Cassava (Manihot esculenta Crantz)	Cassava leaves	6 - 8
2. Dbupa (Veteria indica)	Dhupa meal	70 - 73
3. Groundnut (Arachis hypogaea)	Groundnut vines (Stems & leaves)	41 - 57
	Groundnut meal	53 - 57
4. Guar (Cyampsis psonaloides DC)	Guar meal	70 - 80
5. Kakan (Salvadoza oleoides)	Kakan meal	55 - 58
6. Karaj (Pohogomia pinnata)	Karaj meal	55 - 60
7. Kakum (Garcinia indica chois)	Kakum meal	40 - 42
8. Kusum (Schleichara oleosa)	Kusum meal	67 - 70
9. Mahura (Madhuka indica)	Mahua meal	35 - 40
10. Mango (Mangifera indica)	Mango kernel	50 - 55
11. Nahor (Mesua ferrca linnn.)	Nahor meal	60 - 62
12. Neem (Azadirachta indica)	Neem meal	45 - 50
13. Oak (Obercus dilatata)	Oak meal	60 - 62
14. Pineapple(Annanas comosus)	Pineapple waste	60 - 80
15. Pisa (Actinedaphne hooberi)	Pisa meal	40 - 42
16. Sal (Shorea robusta Gaerth)	Sal seed meal	35 - 40
17. Sesame (Sesammum indicum L.)	Sesame cake	60
18. Soyabean (Glycine soya)	Soya bean	70 - 75
19. Sweet potatoes (lpomoea batatas)	Sweet potato vines (stems + leaves)	24 - 35
20. Tamarind (Tamarindus indica)	Tamarind seed hulls	30 - 35
	Tamarind seed kernels	60 - 65
II. Animals		
21. Poultry	Poultry litter (dry)	26.0*
22. Ruminants	Blood meal	0.6+
	Meat and bone meal (dry)	25 - 30**
	Rumen contents (wet)	0.8+

* Based on a daily faecal production of 100 g adult bird.
** Of the weight of wet offals.; + =Of the live weight.

TABLE 6

AVAILABLLITY OF BY-PRODUCTS FROM FIELD CROPS IN ASIA AND THE PACIFIC

(1982, 10^3m tons)+

Country / Field crop By-product	Castor*	Cassava*		Cotton *	Maize*		Rapeseed*		Broken	Rice Husk	Bagasse	Sugar cane Green tops	Total availability	As % of total production
	meal	leaves	waste	seed meal	Germ meal	Stover	Bran	Meal						
Bangladesh	-	-	-	5.1	0.2	0.7	37.5	73.5	945.0	3360.0	963.4	1243.3	6634.5	3.5
Burma	-	6.0	23.5	46.3	39.4	168.2	0.3	0.6	630.0	2240.0	338.4	433.7	3936.4	2.1
D.Kumpuchea	-	18.0	85.5	1.7	18.7	79.8	-	-	67.5	240.0	17.5	32.7	551.4	8.3
India	143.5	663.3	3173.2	1670.3	1106.0	4712.5	720.7	1417.8	3066.0	9520.0	24792.3	32138.2	83121.8	48.7
Indonesia	-	1536.6	7296.0	8.5	646.0	2755.0	-	-	1534.7	4774.6	2942.2	3814.0	25307.6	13.3
R.Korea	-	-	-	1.3	19.9	34.8	-	6.1	328.9	1169.3	--	-	1610.3	0.8
Laos	-	8.6	41.0	6.3	5.6	23.9	-	-	53.2	189.4	4.1	5.3	337.9	0.2
Malaysia	-	45.0	213.8	-	1.5	6.5	-	-	92.8	329.9	114.8	143.0	953.1	0.5
Nepal	-	-	-	-	104.0	443.7	-	-	103.5	368.0	5.3	65.5	1137.0	0.6
Pakistan	16.6	-	-	1008.5	161.5	688.8	72.6	142.8	225.0	866.0	4938.3	6401.5	11455.6	7.6
Philippines	11.9	276.1	1311.0	6.4	590.8	2519.4	-	-	315.6	1335.4	2835.0	3675.0	12936.6	6.8
Sri Lanka	-	60.0	285.0	5.1	3.9	16.7	-	-	96.8	344.6	50.0	65.1	926.6	0.5
Thailand	15.2	2521.0	11970.0	51.4	510.7	2177.9	-	-	787.0	2800.0	4077.0	6285.0	30195.7	15.9
Vietnam	1.0	319.9	1519.0	2.1	82.7	253.1	-	-	420.1	2204.8	594.0	770.0	6466.7	3.4
Fiji Is.	-	11.4	54.2	-	0.7	2.9	-	-	0.8	2.7	549.5	712.3	1334.5	0.7
Papua New Guinea	-	11.8	55.9	-	-	-	-	-	-	0.3	17.4	22.5	107.6	0.1
Total	188.2	5482.7	26028.1	2813.5	3290.6	13933.9	831.1	1640.8	3921.4	29618.1	42285.2	54808.9	189902.0	100.0

+ Calculated from F.A.O. Production Yearbook (1982).

TABLE 7

AVAILABILITY OF BY-PRODUCTS FROM TREE CROPS IN ASIA AND THE PACIFIC

(1982, 10^3 m tons)+

Country	Tree Crop By-product	Cocoa Bean waste	Cocoa Pods husks	Palm press fibre	Oil Palm Kernel meal	Palm oil mill effluent (Dry)	Rubber++ seed meal	Total	As% of total production
Indonesia		1.1	10.5	390.4	65.0	65.0	64.9	596.9	14.2
Malaysia		6.8	21.8	2415.8	402.5	402.5	158.5	3417.6	81.2
Philippines		0.6	1.8	6.7	1.1	1.1	--	11.3	0.3
Sri Lanka		0.3	0.9	--	--	--	10.6	11.8	0.3
Thailand		--	--	20.3	3.4	3.4	30.8	57.9	1.4
Papua New Guinea		4.7	14.0	76.1	12.7	--	--	107.5	2.6
Total		13.5	58.7	2909.3	484.7	412.0	264.8	4203.0	100.0

\+ Calculated from FAO Production Yearbook (1982)

++ Calculated from the land area under mature rubber in 1977 and the assumption that the average rubber seed production from mature rubber trees is 1000 kg/ha/yr (see Reference de Padirac, 1977).

2.5 Qualitative aspects and nutritive value

This section addresses itself to a brief description of as many the non-conventional feedstuffs as is possible. It is not intended to present an exhaustive account of this aspects, but only some idea of the nature and extent of the individual constituents. Extensive information is available on the nutritive value of feeds from India (Sen and Ray, 1971; Ranjhan and Kehra, 1976), Thailand (Holm, 1971), the Philippines (Zamora and Baguio, 1984), Malaysia (Devendra, 1975a; 1979b) and Indonesia (Hortardi *et al*., 1980). More recently, and based on the available data tables of feed composition applicable to South East Asia have been published (Harris *et al*., 1982). Appendix I provides the chemical compositional profile of NCFR in the Region. Some of the limitations relating to the use of feeds, such as the presence of toxic components are dealt with in the following section on the current status of utilization of NCFR.

2.6 Current constraints to utilization

The NCFR of the Region are presently underutilized. There are several reasons for this state of affairs and their enumeration is important:

a) Production is scattered and in some cases, the quality produced is low, especially for processing.

b) High cost of collection of some of the NCFR eg. rubber seeds.

c) Non-competitive costs and unremunerative prices.

d) Tendency to think of some NCFR eg.palm oil mill effluent in terms of disposal, not utilization.

e) Processing is difficult and in any case problematical.

f) Lack of managerial and technical skills to utilize the feeds *in situ*.

g) Limitations in the end uses of the produced products.

h) Uncertainty about the marketability of the end products.

i) Associated with (e) lack of managerial skills and capital resources for the purchase and operation of suitable technology, or for the study of new appropriate technology.

j) Small farmers who from the backbone of traditional agriculture in the Region have neither the resources and know-how nor the quantities of residue to take individual action. (Devendra, 1983a).

In addition to these and with specific reference to NCFR utilization, there are additional major constraints that merit attention:

a) Availability in terms of time, location, seasonality, and storage facilities.

b) Convertibility with respect to handling, separation, transportation and physical processing of the residues.

c) Limited knowledge on the composition of the residues, such as proximate components (eg. crude protein, crude fibre and minerals) intake and nutritive value (eg. digestible energy and proteins) which are pertinent to the development of utilization technology.

d) Use of the end product in relation to demand, rate of growth of demand, storage and markets, and

e) Inadequate demonstration of potential value in feeding systems both nationally and regionally due to low priority research.

f) Economic viability of residue utilization programmes involving NCFR also needs to be demonstrated.

These constraints together emphasize that the opportunities for overcoming these, and therefore increasing the utilization of NCFR are quite enormous. This can augment the development of suitable technology to make NCFR renewable resources and the quantity of usable feed supplies presently available.

3. CURRENT STATUS OF UTILIZATION OF NCFR

3.1 Non-conventional feeds from field and plantation crops

3.1.1 Banana

There are two by-products from banana cultivation that are potentially valuable feeds: banana rejects or wastes and banana stems. These are produced in siginificant quantities in the Philippines, Indonesia and some of the Pacific islands. Waste bananas are fed directly to buffaloes, cattle, small ruminants and pigs and this has been satisfactorily done in the Philippines especially when the fruit is fresh when fed. However, the extent that this system can develop is limited by the distance of producers from banana packing houses. Reject bananas have also been used as a fermentation substrate for single cell protein (S.C.P.) production (Sequido et al., 1979)

Banana stems are another by-product of banana cultivation. These stems are usually discarded and allowed to rot. However, Chinese farmers have for a long time been feeding these to pigs in several countries in the Region. The value of the stems is as a source of minerals which are concentrated in the pith of the stems. Banana stems have been used as one of the ingredient in the Lehmann system of feeding, and has been shown to be comparable to, and cheaper than all concentrate diet in Malaysia (Devendra, 1963).

3.1.2 Cassava

Two by-products are available from cassava roots, which are valuable as a concentrated source of energy. One is cassava peelings which are usually discarded during the manufacture of cassava chips for feeding animals, especially ruminants. Quite often the peelings are not removed and are a component of the chips.

The second by-product is cassava pulp or waste, due to the manufacture of cassava flour. This waste is usually collected wet from the factories and fed directly to pigs with a protein concentrate. In Thailand, it is usual to dry this waste and then sell it as an animal feed. In India, cassava pulp replaced 50% of the ragi flour in diets for layers which have been shown to lay about 12% more eggs (Pillai *et al.*, 1968). Cassava residue fed with urea and molasses have also been found suitable for growing lambs in India (Krishna Reddy and Reddy, 1979).

3.1.3 Coffee

Two by-products are produced from the coffee plant: coffee hulls and coffee pulp. The utilization of both by-products is relatively unimportant at the moment due mainly to their low availability, but this situation could possibly improve in time with increased yield of the crop in some countries in the Region. Limited work by Abdul Rahman and Mohd Khusahry (1982) in Malaysia revealed that a 20% level of coffee pulp-hull mixture was beneficial to pregnant goats. In India, spent coffee, or by product from the coffee extraction plant has been found to contain 16.3% crude protein, 12.7% ether extract and 38.4% crude fibre. When fed to female buffalo calves, it did not furnish adequate metabolisable energy (Murthy, Sampath and Das, 1979).

Elsewhere, it has been used extensively in diets for ruminants in Guatemala (Bressani *et al.*, 1974, Jarquin *et al.*, 1974) and East Africa (Ledger and Tillman 1972). Of the two, coffee hulls are much poorer in nutritive value probably due to the high lignin content. Bressani *et al.*, (1974) reported in studies with young and adult ruminants that levels of about 20% of coffee hulls showed decreased weight gain, feed efficiency, nitrogen retention, dry matter and protein digestibility. Ledger and Tillman (1972) showed on the other hand that the addition of 10 to 20% levels did not affect feed intake, feed conversion and live weight gain of Boran steers; the performance was however reduced when the coffee hulls were increased to a 30% level. The conflicting results are probably due to the high lignin content and also differences in caffeine content (Bressani *et al.*, 1974) and also to other components in the diet.

3.1.4 Cowpea

This is a leguminous fodder that is available in smaller quantities compared to groundnut vines and haulms from cow pea (Vigna sinensis) cultivation. The roughage is a valuable source of feed for all ruminants. Few studies have been reported on its feeding value and comparative performance, but in India stall feeding either the green haulms or dried hay in lieu of grazing indicated high dry; matter intake (3 to 4.0% of body weight), digestibility and also milk production in Jamnapari goats of 690 to 860 g/day (Maheswari and Talapatra, 1975).

3.1.5 Maize

The residues from maize are of three categories: stalks; husks, skins and trimmings; and cobs. The grain is recovered from the cob by dehusking the ear. Each hectare produces about 3-4 tonnes of stalks (stover) during harvesting, and the approximate yields of the residues are 35% grain, 30% husk and skins, 30% cobs and 5% skins and trimmings. In addition, maize bran and germ meal are also produced from the grains.

The maize by-products in the Region are mainly produced in India, Indonesia, the Philippines, Thailand, Pakistan and Nepal. The production of stover alone is about 11 million metric tons in the Region. The coarse stalks and cobs are usually burnt and the ash ploughed back into the soil, or alternatively, used as fuel. Shredded cobs are exported from Thailand, while in India and Indonesia, they are used as a soil conditioner. Cobs are also used in India to produce furfural and as a moisture absorbent in stored grain.

The current pattern of utilization of the by-products is similar, especially in those countries where maize is cultivated extensively. The softer stover, along with the husk, skin and trimmings are usually fed to ruminants. The harder portions are used for making silage or compost.

In the Philippines, maize stover has been fed *ad libitum* with graded levels of concentrate (0.75, 1.0, 1.25 and 1.5% of body weight) to grade Philippines cattle for 184 days. Significant differences were noted between treatments ($P < 0.05$), and the highest daily live weight gain was found for the highest concentrate supplementation. It was found that in terms of feed efficiency, 30% concentrate supplementation (1% of body weight) and 70% maize stover were necessary (Aglibut, Madamba and Perez, 1972). In Indonesia, supplementation with fish meal and soyabean meal promoted an average daily gain of 813 g/head in Ongole crossbred cattle (Panguti and Djajainegara, 1979).

In India, maize stover fed with 1 kg concentrates or sprayed with 1% urea mixed with either 5 or 10% molasses failed to supply the nutrient requirements of Surti buffalo heifers (Balasubrainanya et al., 1980). The results clearly indicated that maize stover alone was inadequate, and some degree of concentrate supplementation is necessary for good performance.

3.1.6 Millet

The cultivation of millets is confined to India and Pakistan. The residues from millet and sorghum are mainly the stovers, and currently, these are extensively used in these countries, notably in India and Pakistan. Studies on intake and digestibility of bajra (pearl millet) stover with buffaloes in India indicated that voluntary intake of the stover was not influenced by type of supplemental N or barley. However, total dry matter was greated with rations containing groundnut meal or guar meal than urea. All the supplemented diets had higher digestibilities of protein and fibre than stover alone (Sharma and Singh, 1973).

3.1.7 Rice

Rice production represents the most important component of agriculture in most countries in the Region. In many of the countries, the rice milling industry is advanced and is associated with important agro-based industries. One reason for this development is that rice production generates several important by-products: rice straw, rice husk (15-17%), broken rice (4-5%) and rice bran (6-10%). The advent of high-yielding varieties and also double cropping has resulted in increased yields of the by-products which for feeding farm animals in several countries. However, it is doubtful if all these available by-products are effectively utilized.

i) Broken rice

Broken rice comprises mainly of germs, chipped and broken kernels. Because of its low fibre content and high energy value, it is a valuable energy geed, especially for substituting other energy feeds in diets for pigs and poultry. In this connection, several studies have shown that broken rice can easily substitute maize without any loss in performance.

In Malaysia for example, broken rice has been used of levels of 30, 40 and 50% compared to a control diet with maize (50%) in growing pigs, and no differences were found in live weight gain, feed efficiency and carcass characteristics (Mellish, Devendra and Mahendranathan, 1973). More recently in Thailand, broken rice has been used at levels of 50.7% in broiler diets (Khajarern et al., 1979a), 51.9% in replacement layer diets (Phalaraksh et al., 1978), 43.0% in layer diets (Phalaraksh, Khajarern and Puyadolphirod, 1979) and 53.8% in diets for growing finishing pigs (Khajarern et al., 1979b) to substitute traditional feeds without loss in performance.

ii) Rice Husk

Rice husk or hulls constitutes another by-product of rice production. Althout they are not as important as rice straw or rice bran for animal feeding in nutritional value, especially to ruminants, it is nevertheless a valuable roughage source. In rice milling, approximately 17% of the padi yield results in husk.

Most of the rice husk presently produced in the Region is burnt or wasted, and little or no attempt has been made to feed it to ruminants. In areas adjacent to rice mills, the waste product is also a pollutant and when it is burnt produces fumes and ashes which are undesirable. Some attempt has been made however to seek industrial uses, notably in cement mixes.

Elsewhere in the rice growing countries, attempts have been made to feed the husk to cattle (Chandra and Johri, 1953; Noland and Ford, 1955; Rusoff, Frye and Epps, 1956; Kehar, Chandra and Johri, 1959; Ray and Child, 1963; Ray 1964; White, 1965; Horton and Flynn, 1967), buffaloes (Campos and Eusebio, 1967), poultry (Fraps, 1946; Richardson, Epps and Watts, 1956), pigs (Scott and Noland 1958; Noland and Scott, 1963) and horses (Guiliani, 1918).

For ruminants, the majority of these studies evaluated the value of rice husk as a roughage source, while for pigs and poultry, small quantities of finely ground rice husk was used as a diluent of other high energy feedingstuffs (see for example, Richardson, Watts and Epps, 1958). The approach with ruminants was to feed low levels in view of the poor nutritive value (Sakurai and Kato, 1955), since high levels are dangerous (Fraps, 1904). Feeding a diet with 5% rice hulls with long hay to steers showed that 16 of the 23 animals were found with liver abscess (Harvey, 1967). In India, rice husk has been substituted for rice straw in diets for 13-15 month old Hariana x Jersey calves, and it was observed that the rate of growth declined to 42.5, 65.8 and 48.1% at 33, 66 and 100% levels of substitution compared to the control diet (Mathur and Gupta, 1974).

Attempts have also been made to increase the nutritive value of rice husk by increasing the crude protein content through the process of ammoniation (Soonier, 1963; Eng, 1964; White, 1966), delignification (Rajkumar, 1974) and desilication. A 6% level of ammoniated husk for example gave the highest dressing percentage in cattle finishing rations (Tillman et al., 1969). Excluding the feeding value to animals, rice husk also finds important uses in a variety of industrial functions such as fuel, board and paper manufacture, fertilizers, abrasives, chemical and building materials; the latter has recently been reviewed (Chittanden, 1971).

Studies have recently been completed in Malaysia on the utilization of rice husk in iso-nitrogenous molasses-based diets in sheep. It was found from the apprent digestibility coefficients and also the nitrogen retention data, that the best results were consistently obtained with the 5% of rice husk inclusion (Appendix 2, table 1). It was also calculated that the mean daily digestible energy (DE) intakes of the sheep in treatments one to six were 1.428, 0.993, 1.105, 0.942, 0.831 and 0.696 Mcal., respectively (Devendra. 1977c).

The ash digestibility decreased significantly with increasing level of rice husk utilization, and was 23.9% at the 30% level of inclusion compared to 83.5% at the 5% level. This decreases in the former was about one quarter of the latter and is related to the high content of silica in the rice husk. The reduced digestibility of the main constituents suggests that the by-product is mostly excreted. In lambs for example, 97% of the silica intake was excreted, of which 99% was in the faeces (Fahmy et al., 1968).

As a roughage source therefore, there is no doubt that only small levels, of about 5% rice husk in the total diets, can be included to give the best results. Support for this finding is found in the results of practical feeding trials of Tillman et al., (1969) who demonstrated that 3% raw husk gave the best dressing percentage in bullocks, and in digestibility studies with steers where a 5% level of husk gave a higher digestible energy value than the 20% level (White, Reynolds and Hembry, 1971). In relation to the high digestibility of dry matter recorded in the study (91.7%) one advantage of the 5% level of rice husk is that it is apparently a suitable carrier of high levels of dietary molasses, in this case about 83%. At such low levels of inclusion therefore, rice husk can be a useful ingredient in the feeding of high levels of molasses to the ruminants.

It is conceivable that higher level, of the order of about 10% can be used, provided the rice husk is ground so that it can be more easily digested by the rumen micro-organisms. This point has recently been investigated in India. It has been shown that fine milled rice husks can completely replace rice bran in the concentrates for milking Murrah buffaloes without producing any ill effects (Santos, Eusebio and Villaviza, 1979). Rice husk diets when compared to cottonseed husks or cottonseed sawdust fed to beef cattle (McCartor, England and Hefley, 1972), gave a daily weight gain which was as good as cottonseed husk and better than cottonseed sawdust. The feed efficiency was superior (7.34 kg/kg) compared to 7.49 and 7.70 kg/kg respectively. This approach can also form the basis of feeding regimes where the intention is to dilute the energy density of the diet, as in high fat diets.

3.1.8 Sago (*Metroxylon spp.*)

The sago palm produces valuable carbohydrate by-product feeds. These include unprocessed sago pith and sago refuse produced from the manufacture of sago starch. The process starts with the use of sago trunks from which the bark is first removed. Over 90% of the material is then used to produce the sago rasp from which about 20% sago starch is produced. The remainder of about 80% is sago waste. The total quantity of sago pith for feeding animals in Indonesia and Malaysia is about 40,000 mt per year.

Sago waste when produced is very wet. Usually pig farmers purchase it and feed it directly to pigs as a source of carbohydrates together with some protein supplementation. It can also be dried and then fed to animals. No investigations have been undertaken on the value of this by-product in diets for farm animals, and its value as an energy source merits research. It is also a valuable growth media for microorganisms.

3.1.9 Sugarcane (*Saccharum officinarum*)

i) Bagasse

Bagasse, the residue after juice extraction from the sugarcane plant, is an important by-product from sugarcane cultivation in a number of countries in the Region. It constitutes approximately 15-20% of sugarcane tops with a moisture content of about 50%. At present, the material is used mainly as a fuel in sugar factories, and on a limited scale for feeding animals.

Elsewhere in the tropics, especially in the sugar growing areas of the West Indies, bagasse is also valuable as an animal feed for ruminants. Work (1937) was probably the earliest to report on the digestibility of the by-product. It has been used in diets for ruminants in the U.S.A. (Davis and Kirk, 1962; Brown *et al*., 1959; Kirk, Peacock and Davis, 1962), Queensland (Beames, 1961), Pakistan (Saleem and Huq, 1951; Khan, Qazi and Schneider, 1962; Ghauri, Qazi and Schneider, 1964); West Indies (James, 1969), Mexico (Hochstrasser, Requelme and Rincoon, 1977), and Cuba (Martin *et al*., 1974; Martin, Cabello and Elias, 1976). Kirk, Peacock and Davis (1962) for example, concluded that balanced diets with 20 to 30% bagasse levels for cattle produced rapid and economic gains. In Pakistan, 10% bagasse in the diet produced economical live weight gain in bullocks (Khan, Qazi and Schneider, 1962) whereas a 29.5% level depressed live weight of sheep (Ghauri, Qazi and Schneider, 1964). In Mexico, replacement of 0, 20 and 40% maize silage by bagasse did not significantly depress live weight gain, feed intake and efficiency of feed utilization (Hochstrasser, Requelme and Rincoon, 1977). The value of combined chemical and pressure treatment on bagasse has been demonstrated in Cuba (Martin, Cabello and Elias, 1976).

In the Philippines, Roxas, Perez and Trinidad (1969) determined the digestibility of bagasse-based diets (40-60%) fed to sheep, cattle and carabaos, supplemented with molasses, copra meal and wheat pollard. The large ruminants consumed more DMI than sheep which lost weight. Frung and Ordoveza (1978) fed Napier grass and a concentrate mixture containing 31% bagasse to dairy cows and reported that the daily milk production of 6.9 kg was comparable to that dairy cows fed concentrates without bagasse. The amount of bagasse consumed was however very small, around 10% of total intake.

The bulky and fibrous nature of the by-product renders it a suitable feed for ruminants, for example in complete concentrate diets containing bagasse for dairy cows in Puerto Rico (Randal, Soldivela and Salas, 1967). Recently, bagasse has also been fed intact with sugarcane excluding the outer rind, in the form of comfith - a product derived in the West Indies (Donefer, James and Laurie, 1973).

More recently, studies have been initiated in Malaysia on the intake and utilization by sheep fed chemically treated bagasse using either 6 to 8% NaOH or $Ca(OH)_2$. The data indicated that as the level of dietary bagasse (5, 10, 15, 20, 25, 30, 35 and 40%) increased, digestibility decreased. Between alkalis, the results indicated that a 4% NaOH level was suitable and that the optimum level of bagasse inclusion was 20 to 30% in the diet (Devendra, 1979d). Table 12 summarises the results.

ii) Sugarcane tops

Sugarcane cultivation on a commercial scale is common in most countries in the Region. Three important by-products are produced; sugarcane tops, bagasse and molasses. However, only the first two are considered non-conventional, since molasses is used traditionally in feeding systems for farm animals in all countries in the Region.

The present pattern of utilization of the tops is to burn it in the fields prior to harvesting the canes. Where this is not done, the tendency is to feed the tops either fresh, or after drying, as a roughage source to meet the energy requirements for maintenance. There has been limited work on its utilization in feeding systems in the Region. However, its nutritive value has been evaluated *in vitro* in India, and it has been reported (Chaudhary *et al.*, 1972) that digestibility of dry matter and cellulose after 24 and 48 hours incubation was 30.0 to 31.3% and 43.3 to 49.6%, and 27.7 to 29.6 and 30.3 and 34.1% respectively. More recently, Devendra (1983b) has reported in studies with sheep that the nutritive value was 0.7% DCP and 8.44 MJ/kg ME.

In the Philippines, Pepito, *et al.*, (1969) found that the nutritive value of sugarcane tops ensiled with or without molasses was 50% TDN and 9.2 MJ/kg of digestible energy. When fresh sugarcane tops was fed to Holstein Friesian, Santa Gertrudis x native or Jersey steer for 115 days, supplemented with concentrates rice bran, molasses and copra meal), the daily live weight gain was 0.51 and 0.42 kg respectively (Pepito, 1966) Sugarcane tops silage (60% in the diet) supplemented with 20% level each of molasses and coconut cake and fed to bulls gave a live weight gain of 0.41 kg/day with a feed efficiency of 12.6 kg air dry feed/kg live weight gain (Tuazon, 1974). The last two studies clearly indicate that the tops cannot be fed alone and need to be supplemented with some concentrates to achieve any response.

In some countries of the Region, such as in parts of Pakistan and Fiji, the tops are not burnt and are therefore available for feeding. However, because of problems of collection, transportation and often lack of ruminants in areas where the material is produced, the feedstuffs are usually wasted and not put to effective use. Sugarcane tops can also be ensiled easily as the studies in the Philippines have shown, but there is little evidence of this being produced and used in the Region.

3.2 Non-conventional feeds from tree crops

3.2.1 Cocoa

Several studies have been reported concerning the utilization of cocoa pod husks (CPH) in diets for poultry (Adeyanju et al., 1975a), pigs (Braude and Foot, 1942; De Alba and Bassadre, 1952; Oyelaja, Stratman and Tompkins, 1970; Omole and Adegbola, 1975) and in ruminants (Aplin and Ellenberger, 1927; Richter and Brueggemann, 1937; Haines and Esheverrita, 1955; Greenwood-Barton, 1965; Bateman and Larrangan, 1966; Bateman and Frensillo, 1967).

Two of the earliest experiments of CPH utilization were by Lindsey and Smith (1914) in ruminants and by Braude and Foot (1942) in pigs. CPH has been used in diets for farm livestock in several studies in Costa Rica: Bateman and Larrangan (1966) for example, compared CPH to cassava meal and maize; it was found that cows fed CPH produced a comparable yield of milk to those fed maize. In Nigeria, studies by Adeyanju et al.,(1975b) found that both sheep and goats can tolerate approximately 25% cocoa pods in maintenance diets.

More recently, studies have been conducted in Malaysia concerning the digestibility of increasing levels of CPH when fed to sheep (Devendra, 1977e). The pods were used to replace cassava chips in molasses-based diets at levels varying from 10 to 50%. A mainly cassava-molasses diet with no CPH acted as control. The crude protein contents in the diets were kept isonitrogenous at 12% in which urea supplied 66 to 77% of the total crude protein requirements.

The results indicated that the digestibility of the dry matter and organic matter dropped significantly at the 40 and 50% levels (Appendix 2, table 3). The finding that a 30% level of cocoa pod inclusion is optimal is in reasonable agreement with the results of Adeyanju *et al*., (1975b) referred to above. More recently, further confirmation of this optimum level has been reported in feeding trails in Sabah, where imported Australian cattle in feedlot gave an average daily gain at 0.7 kg/head (Bacon and Anselmi, 1984).

The decrease in dry matter digestibility beyond the 30% level of inclusion, may be due to the presence of the alkaloid theobromine (3, 7-dimethylxanthine) which has deleterious effects on animals (Ellenberger and Newlander, 1924; Temperton and Dudley, 1943). However, since it is also known that cocoa pods contain only traces of theobromine (Haines and Esheverrita, 1955; Greenwood-Barton, 1965), this may not have been entirely responsible for the depressed digestibility. It is possible that this depression may have been caused by tannins and the related phenols and more particularly increasing crude fibre content in the diet with increasing dietary cocoa pod inclusion. The crude fibre content is high in the pods and was found on average to be 31.4%.

No differences in the digestibility of crude protein were noted with cocoa pod supplementation but these were significantly lower than the control diet. The 30% CPH level gave the highest N retention of 30.6% as percentage of intake. This was however significantly lower than the control diet of 44.4% (P/0.05).

The digestibility of crude fibre increased up to the 30% level of inclusion and then declined. The highest crude fibre digestibility, not-significant at this level (30.0%) was 32.6%. Adeyanju *et al*., (1975b) also reported increased crude fibre digestibility with increasing level of cocoa inclusion. These authors found that the digestibility of crude fibre increased from 34.8% at a 12.5% level of inclusion to 39.0% at a 25.0% level. The results together demonstrated that cocoa pods can be incorporated into feeding systems suitable for sheep. This would apply also to other ruminants. This conclusion is important for countries like Malaysia where the availability of cocoa pods is increasing.

One of the problems concerning the utilization of CPH is its rapid deterioration. Feeding the fresh pods therefore has disadvantages, and in order to reduce the feeding of decomposing CPH, it is common to first dry the husks and grind them before feeding. A high theobromine content is caused by fermentation of the shells before drying, and can be toxic to farm livestock, as reported for pigs (Braude, 1943). On the other hand, at very low levels, the alkaloid acts as a mild myocardial stimulant and a diuretic. Combined heat and chemical treatment cab reduce the theobromine content markedly, with little effect on the amino acide level (Omole, 1970; Orok and Bowland, 1974). Attempts have been made to detheobromize the cocoa oil cake by cooking in water for 1.5 h, filtering and drying; up to 25% of the processed product has been included in diets for pigs without loss in performance (Braude and Foot, 1942). This method is however impractical and is also expensive.

Considered together, that is in terms of optimal utilization and also meeting the energy requirements for maintenance, the results suggest that 30-40% levels can be used in the diet of sheep. It is relevant to note in this connection that in Costa Rica, 40-50% levels of cocoa pods have been used in the diet of bovines (Bateman and Larrangan, 1966). The feeding value of by-products from cocoa and coconuts has recently been reviewed (Devendra, 1978a).

3.2.2 Oil Palm

Oil palm by-products are good examples of NCFR which are emerging as important new feeds. This is associated with the rapidly expanding land area under the crop in some countries, notably Malaysia. Table 8 summarizes the present and projected availability of the by-products in Malaysia.

Figure 1, illustrates the approximate amount of principal products and by-products that are available from the oil-palm at maturity.

The availability has been calculated using the planted are (present and projected) of mature palms with the following considerations:

i) First,third of the area is in the younger age groups which is in the first and second year of harvesting (average yield: 13.1 tonne/ha).

ii) Next, one-fourth to be in the medium age groups which is in the third and fourth year of harvesting (average yield: 23.6 tonnes/ha).

TABLE 8

AVAILABILITY OF OIL PALM BY-PRODUCTS IN MALAYSIA[+]
(1976-1998, 10^3t)

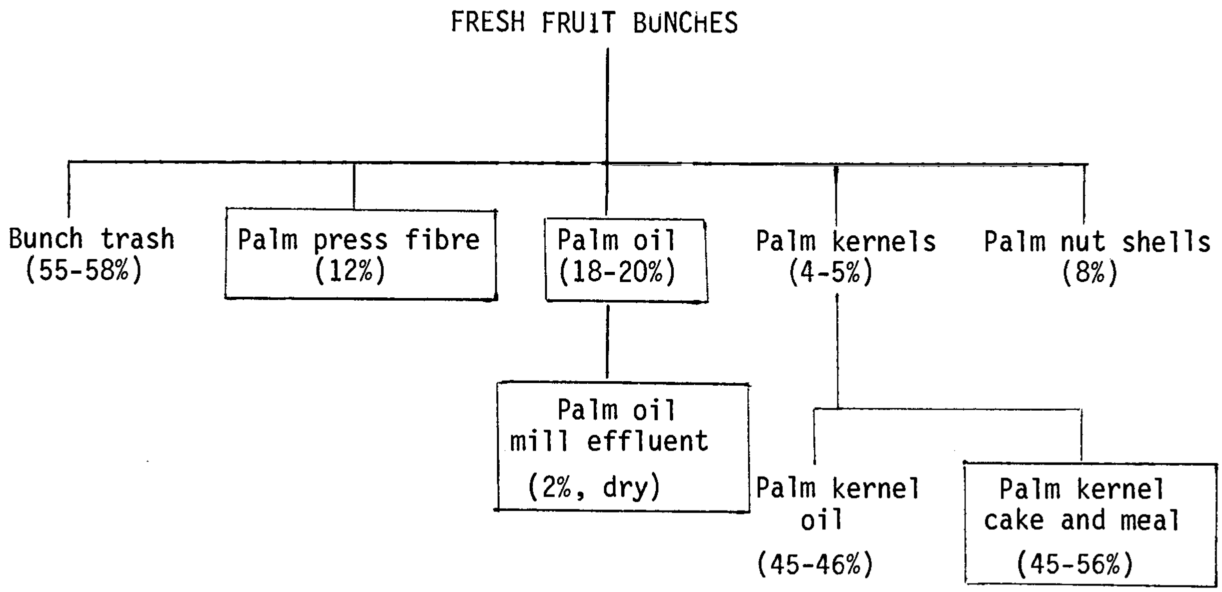
By-product	1976	1980	1984	1998
1. Palm press fibre	984.0	1623.7	2737.3	3587.3
2. Palm oil mill effluent	27.7	53.9	86.7	113.6
3. Palm kernel cake [++]	177.1	292.2	467.1	612.1

\+ Calculated from the total land area under the crop and from projections (hand area), from Anuwar (1984).

++ Includes palm kernel meal (solvent - extracted).

FIGURE 1

APPROXIMATE AMOUNTS OF PRINCIPAL PRODUCTS AND BY-PRODUCTS FROM THE OIL PALM AT MATURITY[1]



[1] Maturity here refers to the 1st year in which a commercially processible crop in harvested. The data above refer to the year in which the highest production is obtainable (normally the 6th to 7th year of harvesting). Figures in parentheses refer to approximate proportions expressed as per cent of fresh fruit bunches.

Note: Allowance has been made for a probably loss of about 1%.

iii) The remaining land area is completely mature palms which is in the fifth year of harvesting (average yield: 19.6 tonnes/ha).

It is clear that the availability of the by-products in the future will be quite substantial, and effective use of these must also consider potential feeding value to farm animals.

A number of studies have been conducted to assess the utilization of palm press fibre (PPF) and palm oil mill effluent (POME). The results of these studies have been reviewed (Devendra, Yeong and Ong, 1982) but are briefly summarized below together with the results from more recent studies.

i) Palm Press Fibre (PPF)

The digestibility of PPF varying at levels from 10 to 60% was determined in balance trials using sheep (Appendix 2, Table 4). The digestibility of dry matter was highest with 10% inclusion of PPF. Both crude protein and crude fibre digestibility decreased with increasing level of PPF. Ether extract digestibility increased with increasing level of PPF inclusion, and significant differences were noted between treatments. It was concluded from these studies that the optimal level of PPF inclusion of 10%. In a continuation of the programme, the effect of chemical treatment using NaOH or Ca $(OH)_2$ did not improve digestibility of crude fibre in PPF due to the formation of soaps (Devendra and Muthuraja, 1976; Devendra, 1978b).

Camoens (1979) fed PPF alone to dairy bulls and recorded up to 2-8% DMI as percentage of body weight. With supplemental concentrates, the intake of PPF dropped to 1-7% by the total DMI increased to 4-2% of body weight. The importance of supplementation has also been demonstrated by Dalzell (1978). PPF with or without cassava chips gave poor growth rates (0.05 - 0.08 kg/head/day) and (0.12 - 0.18 kg/head/day) in swamp buffaloes and cattle, respectively. With added palm kernel cake (PKC) however, the growth response increased to between 0.28 - 0.37 kg/head/day and 0.23 - 0.41 kg/head/day for buffaloes and cattle respectively. The poor performance in the diets without PKC was also caused by the presence in the diet of up to 30% levels of palm oil mill effluent (POME) which fed in the wet farm effectively decreased the net energy uptake by the animals.

More recently, various PKC:PPF ratios (90:10, 70:30, 50:50) have been fed to Australian Commercial Crossbred cattle in Malaysia and daily growth responses of 563, 428 and 336 g/head have been reported for the three ratios respectively (Hutagalung, et al., 1984). The highest growth response of 563 g/day for the 90:10 PKC:PPF ratio confirms the earlier finding by Devendra and Muthurajah (1976) that a 10% PPF was optimal in the diet. Aznam (1982) has reported that 42-47% of the DMI of PPF is digested in the rumen of buffaloes and that the content of soluble components were close to that of a basal gran diet.

ii) Palm Oil Mill Effluent (POME)

POME is a general term which refers to the effluent from the final stages of palm oil production in the mill. It includes various liquids, dirt, residual oil and suspended solids. It contains about 95% water.

One of the problems concerned with feeding of POME is the high moisture content. In order to increase the solids content for animals, attempts have been made recently to reduce the moisture content in the effluent. The raw effluent is decanted in a decanter before being dried in a rotory drier. It thus refers to the solids from the crude oil after centrifugation by the decanter. A number of palm oil mills in Malaysia are now increasingly using the decanter system to provide a different type of by-product in the form of palm oil solids (POS). Clearly, this by-product also has considerable feeding potential, but the real value in feeding systems as a medium quality protein and energy source needs more research.

The digestibility of the dry matter of PONE in diets containing 10 to 60% level was high (87.7%), and significant difference existed between treatments. A 10% level of POME gave the best results and this was also consistent with the highest digestibility of energy (Appendix 2, table 5).

Crude fibre digestibility dropped significantly from 80.6% in a 10% POME diet to 27.0% in a 60% POME diet. Ether extract digestibility decreased progressively with increasing dietary POME.

When PPF and POME were combined in equal proportions and fed at increasing levels, the digestibility of DM increased with increasing level of the by-products and was a maximum at the 40% level of inclusion (77.0%). At this level, there were statistically significant differences ($P \angle 0.05$) in the digestibility of DM compared to other treatments. Organic matter, crude protein and crude fibre digestibility followed the same trend (Appendix 2, Table 6).

It should be stressed that the effective utilization of the by-products was achieved mainly by the addition of molasses. In the trials reported, the minimum suitable level of molasses to be used in the diet appears to be 1 part of molasses for every 1.2 parts of PPF + POME. Based on this ratio, the suggested optimum levels of PPF, POME and PPF + POME inclusion when fed signly were 30, 40 and 40% respectively (Devendra and Muthurajah, 1976).

Palm oil mill effluent has also been used to feed cattle and pigs in estates; preliminary indications suggest that with cattle, there is improved live weight gain (Pillai and Tan, 1976).

iii) Other derived feeds from oil palm by-products

Of the by-products from oil palm, palm oil mill effluent is useful for the derivation of other feeds suitable for animals. This involves biological, chemical and physical treatment effects whereby the liquid slurry is fermented or biodegraded with other feed ingredients like cassava (*M. esculenta* Crantz). Additionally, the sludge component can be separated to produce the solids and oil waste water. The former is a valuable animal feed, and the latter can be used for fermentation processes to produce single cell protein (SCP), and possibly also chorella, which are both valuable animal feeds.

iv) Palm Oil pollution

One unfortunate consequence of the growth in production of palm oil is the problem of pollution caused through its by-products. It is estimated that the current annual output of palm oil is about five million tonnes in Malaysia: this results in the production of about two million tonnes of POS which pollutes the streams, rivers and seas.

The safety of level of the pollutant in streams and rivers should be no more than 500 ppm biological oxygen demand (B.O.D.), and in the drinking water 50 ppm B.O.D. Present levels in streams and rivers are very much higher; up to 20,000 B.O.D. has been recorded. If the process of effluent discharge into streams goes on uninterrupted, the solids in running water can go up to 250,000 tons annually. Various methods have been suggested to minimize this:

1. Increase the utilization of POS directly by animals (non-ruminants and ruminants). This can be achieved by feeding the POS directly to the animals in the estates where it is produced, or after it has been processed into an animal feed through biodegradation techniques. Both avenues need to be investigated in depth. Direct utilization of POS where it is produced has several advantages:

a) the store life of POME and PPF is short, probably no more than 36 hours, so that direct utilization is consistent with minimum wastage.

b) the palatibility of the by-products is highest immediately after it is produced.

c) the problems of transportation due to bulkiness of the by-products are overcome.

d) pollution is effectively controlled, and

e) agricultural diversification to include animals may bring about more complete utilization of the resources and greater profits.

2. Evolve suitable engineering and biological methods that would reduce the high moisture content in POME and concentrate the solids in the dehydrated products. Upgrading the quality of this concentrate product may also be considered.

3. Design suitable equipment that will reduce the pollution load of oil palm wastes into running waters to acceptable levels (200 ppm B.O.D.)

4. Control through legislative measures.

3.3 Non-conventional feedstuffs from fruit processing

3.3.1 Bananas

Banana wastes are by-products of banana harvesting and packing for human consumption. In the Region, banana wastes are found mainly in India, Thailand, Philippines, Pakistan, Vietnam and Malaysia. In most of these countries, these are usually fed to cattle, buffaloes, goats, sheep and pigs which relish the wastes. However, the extent to which the bananas can be such good use is limited by the distance of producers from banana packing houses. Two main varieties, *Musa sapientum* L, and M. *paradisica* L. are involved. The discarded waste fruits usually represent about 10 to 20% of the total crop, but this varies with the efficiency of harvesting and packing of the fruits.

Bananas have a high energy and low protein content. They can be fed raw, in the form of chips or as silage. The last of these is favoured by the high fermentable sugar content of green bananas. Moreover, the starch in ensiled green bananas keeps well. The tannin content in green bananas is high, but this decreased with increasing polymerization of the ripe fruit. Apart from feeding, reject bananas have also been used in recent years as a fermentation substrate for single cell protein production.

In the Philippines, reject bananas have given excellent results as supplement to molasses-urea diets. Preliminary results from a 160 days feeding trial indicate that a daily intake per head of 3 kg fresh fruit (containing approximately 460 g starch) increased the growth rate of 200 kg steers by 20% when the basal diet was sugarcane/urea and Leucaena leucocephala (McEvoy and Preston, 1976). Salting et al., (1978) reported that steers fed green banana rejects, banana meal (bananas chopped/sliced and dried), and para grass supplemented with concentrates gave daily gains of 0.59 - 0.67 kg/day which were not significant.

Outside the Region, useful studies have been conducted in the West Indies. Shillingford (1971) has reported on the economics of feeding banana waste and coconut meal for pork production in Dominica, and noted that the degree of ripeness of the bananas had little influence on performance. In Guadalupe, Le Dividich and Canope (1975) fed fresh bananas and banana silage to pigs and found that these feeds were acceptable and suited to growing and fattening pigs.

3.3.2 Mango Kernel

Mango seed kernels are by-products of mangoes (Mangifera indica L) used for human consumption. It comprises the seeds and kernels and possibly also the skins. In countries such as in India, Pakistan and Bangladesh where mangoes are abundant, these by-products are also available in quite large quantities. India alone produces an estimated 1.0 - 1.5 million tons of the by-products. But the feed is dispersed throughout the country and collection presents problems.

Recent work has reported that a 10% level of inclusion is optimum for dairy cattle which produced a daily milk yield of 8 kg/day (Aun, Rpt., ICAR, 1983).

Early work by Kehar and Chandra (1945) indicated that mango seed kernel had a DCP content of 6.1% and a TDN content of 50.0%. Feeding trials with Kankrej calves and Surti buffalo calves for 12 weeks indicated that the optimum level of incorporation in concentrate diets was 20% (Patel, Shukla and Patel, 1971). With working bullocks, Patel, Patel, and Talapada (1972) found a 40% level to be satisfactory.

A concentrate mixture made up of tomato waste, mango seed kernels and Cassia tora seed in the ratio 4:3:2 yielded live weight gains at reduced feed costs (Patel and Patel, 1971) One limiting factor in this feed is the presence of about 5 - 10% of tannins.

3.3.3 Pineapple wastes

Pineapple cultivation and canning of the fruits produce large volumes of waste materials of potential value for livestock feeding in Thailand, Philippines, Malaysia and India. In Malaysia about 1000 tons of pineapple cannery waste is produced annually; its nutritive value is equivalent to cereal grains on a dry matter basis. *Ananas comosus* Merr. and *A. sativus* Schult f. are the common varieties of fruits cultivated.

Pineapple cannery wastes are of two types: cannery wastes and plant residues. Pineapple cannery waste consists of the outer peel (shell), crown and bud ends of the fruit, fruit trimmings, the inner core and the pomace of the fruit from which the juice has been extracted. The ratio of individual portions of pineapple wastes and their chemical composition varies with the variety of the fruit, its ripeness and the cannery technology employed (Mueller, 1978).

Pineapple wastes have been extensively fed fresh to feed lot cattle in the Philippines with considerable success. An alternative approach has been used in Malaysia: ensiling the pineapple wastes together with poultry litter to feed beef cattle. Mueller (1978) has given three examples of the diets used which had 47.5 to 60.0% pineapple cannery wastes, 25.0 to 33.0% poultry litter, 6 to 10% palm press fibre, 1 to 2.0% fermentation industry waste 6.5 to 11.0% molasses/bakery waste and 2.0% vitamin-mineral supplement. The diets were all formulated from ingredients found abundantly in Malaysia and demonstrated good performance in feed lot cattle.

In the Philippines, large scale feeding trials on cattle given pineapple pulp and pineapple leaf silage together with a 35% protein concentrate at 0.6% of body weight gave daily live weight gains of between 0.38 - 0.48 kg (Albarece, 1979). The utilization of the wastes not only from the canning process but also the fibrous residues (leaves and stems) at harvesting time thus represents a potential possibility.

3.4 Non-Conventional Protein Feedstuffs

3.4.1 Plant Proteins: Oil Cakes and Meals

(i) Guar Meal

Guar meal is the by-product after extraction of gum from guar (*Cyamopsis tetragondoba*) seeds. It consists of the outer seed coat and the germ of guar seeds. It is a potential source of protein and has been used to feed livestock and poultry. It contains about one and a half times more protein than guar seed and is comparable to that of other oil cakes. Guar meal in balanced diets does not cause digestive disorders, however it can induce chronic diarrhoea when fed as the sole concentrate to growing calves. In the former case, a growth rate of 581 g/day has been reported (Sadagopan and Talapatra, 1967). Sagar and Pradhan (1975) totally replaced guar meal for groundnut cake and reported that with guar meal the response was 655 g/day compared to 640 g/day with groundnut cake. Kawatra, Rao and Sidhu (1968) replaced 15% groundnut meal by a similar proportion of guar meal in diets for chicks and found that coarse guar resulted in greater body weights than fine guar except when cooked.

There are however, two deleterious factors in guar seed meal. The first is that the meal has a residual gum which is an undigestible polysaccharide that leads to sticky faeces. Attempts are now being made to reduce the gum content in the meal which tends to have a growth depressing effect. The second is that it has a trypsin inhibitor.

(ii) Neem Seed Cake

Neem seed cake is produced from neem (*Azadirachta indica*) seeds after extraction of the oil. It is estimated that about 300,000 tons of neem seed cake are available annually in India. Experiments have been carried out on the response to feeding it to both buffaloes and cattle. With buffaloes, when neem seed cake was used to replace 100% and 75% of the DCP, the DCP and TDN contents were 8.9% and 57% respectively. With calves, even a 25% replacement of the DCP was found to be unpalatable, and a 12.5% replacement of the DCP gave growth rates and digestibilities that were inferior to the control. Some deleterious effects (Bedi, Vijian and Ranjhan, 1975), associated with unpalatability makes neem seed cake not an attractive protein source.

Arora *et al.*, (1975) noted that cattle accepted the cake when it was mixed with maize, but they were reluctant to do so when molasses was used instead. It has been suggested that the causative factor may be a bitter principle, which should be removed. This will affect the value of the cake as a protein supplement in the future. This would alleviate also its limited importance for feeding farm animals presently, compared to its use as a fertilizer.

(iii) Palm Kernel Cake

Palm kernel cake (PKC) like rice bran, is valuable in supplying both dietary energy and protein, but is used mainly as a protein feed. However, the protein content is low, although its quality is high. It also has poor palatability. The high fibre content makes it less suitable for feeding non-ruminants. It is more commonly fed to ruminants especially lactating cattle, in countries such as West Germany and the United Kingdom where it has often been found to raise the fat content in milk.

PKC has been fed to non-ruminants in Nigeria and Malaysia. With rats Fetuga, Babatunde and Oyenuga (1973) showed that good live weight gains can be achieved. But with pigs (Babatunde, Fetuga and Oyenuga, 1974), there was poor utilization and weight loss, and PKC was demonstrated to rank lower in protein quality than other protein sources in Nigeria. Yeong (1981) has recently reported that the ME content of PKC for poultry on an as feed basis was 5.61 mj/kg.

In Malaysia, there has recently been much interest in feeding this by-product to especially ruminants. Three types of PKC are recognised: solvent-extracted meal, expellar and pellet. With sheep, the DMI of the solvent-extracted meal was found to be twice as much as the expellar type. However, the expellar type gave a higher N retention than the solvent-extracted type (Devendra, 1984). It has been used as a complete ration for feeding cattle and growth rates of between 0.74 - 0.76 kg/day have been reported (Mustaffa, Hawari and Rosli, 1984). PKC has also been used to feed dairy cattle successfully (Ganabathi, 1983). One of the problems concerning the feed is the variable quality, partly due to the presence of the shell content.

(iv) Rubber Seed Meal

Rubber seed meal is a valuable protein source and is available, notably in South India, South Thailand and Malaysia.

The crude protein content is about 25%. An assessment of amino acid content suggests that the methionine content is lower than in coconut cake and palm kernel cake, but the lysine and cystine contents are higher. The main limitation in rubber seed meal however, is the presence of hydrocyanic acid - up to 540 ppm. However, both heat treatment and storage can be used to reduce it.

In Sri Lanka a 20% dietary level has been found satisfactory in diets for layers (Buvanendran and Siriwardene, 1970; Buvanendran 1971; Rajaguru, 1973) provided it is suitably supplemented with other protein sources. Siriwardene and Nugara (1972) reported an ME value of 7.49 MJ/kg for the meal. Ong and Yeong (1977) have reported a 20% level of inclusion in pig diets and growth depression was evident beyond this level (Table 9). Limited work appears to have been done which feeding

TABLE 9

EFFECTS OF DIETARY RUBBER SEED MEAL ON PERFORMANCE AND CARCASS CHARACTERISTICS OF SWINE IN MALAYSIA

(Ong and Yeong, 1977)

Parameter	% incorporation in the diet					
	0	5	10	15	20	25
Avg. daily gain (kg)	0.50[a]	0.50[a]	0.49[a]	0.48[a]	0.47[a]	0.41[a]
Avg. daily feed (kg)	1.73	1.83	1.80	1.80	1.82	1.76
Feed/gain	3.51[a]	3.58[a]	3.69[ab]	3.73[ab]	3.83[b]	4.33[c]
Dressing (%)	69.5	68.3	71.7	69.2	69.6	69.9
Carcass length (cm)	71.4	70.7	71.1	70.5	72.2	70.2
Backfat thickness (cm)	2.14	2.23	2.30	2.20	2.36	2.18
Leaf fat weight (kg)	1.13	1.14	1.33	1.16	1.06	1.14

a, b, c - Figures in the same row bearing different superscripts differ significantly (P/0.05).

the meal to ruminants, but a 20% level has been found to be suitable for calves and lactating cows in Kerala (Ann. Rpt., 175-76). More recently, optimum levels of 25% and 30% levels have been reported to be satisfactory for dairy cattle (7-8 kg yield daily) and crossbred calves of 500 kg/day respectively. (Ann. Rpt., I.C.A.R., 1983).

(v) Sal Seed Meal

Sal seed meal is a by-product from Sal (*Shorea robusta*), and is of considerable interest currently in India. Recent estimates suggest that there exists in India, about 175,000 sq. km of land under sal, which has a potential yield of about 6 million tonnes of sal seed kernel. Sal seeds have a valuable oil content, and the residual meal is therefore free from most of the fat.

At present about 40,000 to 50,000 tonnes of sal seed is being processed. The meal has about 10 to 15% crude protein and about 25 to 27% crude fibre. The tannin content appears to be variable, 3.5 to 4.0% (Panda, *et al*., 1969) and 7.6% (Kumar, *et al*., 1970). Verma (1970) determined an ME value of 11.10 MJ/kg. Negi (1982) has reviewed the use of the feed in livestock rations and has concluded that it is comparable to that of poor quality roughages.

(a) Cattle

Considerable work has been done in India on the utilization of sal seed cake by various types of farm animals. Kumar *et al*., (1970) found that the intake of dry matter of bullocks fed ragi straw ad libitum and sal seed meal was 1.1/100.0 kg live weight, giving a TDN value of 4.1% for the meal. The authors also noted that the urine of these animals had flaky sediments. Nagpaul, Verman and Chawla (1973) included up to 50% of the meal in diets for bull and buffalo calves and found no marked differences in the digestibility of the proximate principles. Kurar and Mudgal (1972) included 10,20 and 30% sal seed meal plus 2% biuret in diets for growing heifers and concluded that up to 30% of the meal plus 2% biuret gave optimum growth and utilization in growing heifers.

Shukla and Talapada (1973) fed Kankrej bullocks given hay *ad libitum* and Napier grass (*Pennisetum purpureum*) with a concentrate mixture having 0, 20, 30 and 100% of sal seed meal. The bullocks receiving 100% meal lost 14 kg in 60 days. They concluded that up to 40% meal is optimum in the diet of adult bullocks. A high incidence of indigestion was noted in dairy cows when sal seed meal replaced rice bran (Dash and Misra, 1972). Robb (1976) has reported data on the digestibility of sal seed meal relative to barley and found that the protein digestibility was negative. It has been suggested that this may have been due to the presence of tannins, which may have formed complexes with proteins in the meal to give the negative digestibility. Ahmad and Reddy (1979) have reported that supplementation of 0,5, 10 and 15% sal seed meal in concentrate diets for growing heifers gave no significant effect on growth performance. However, there was a decreasing trend in live weight gain when the meal was increased from 10 to 15%. This result is consistent with the more recent findings that the inclusion of 10% sal seed meal in dairy cattle diets produced a yield of 7.5 kg/day (Ann. Rpt., I.C.A.R., 1983).

(b) Buffaloes

The feeding value of 3% untreated sal seed meal and 0.1% N NaOH treated sal seed meal in a concentrate mixture (isocaloric and isonitrogenous) has recently been evaluated when fed to lactating Murrah buffaloes. While voluntary feed intake was not affected, crude protein, nitrogen-free extract digestibility, feed utilization and milk production were all favoured by treatment with the sal seed meal with 0.1% N NaOH (Singh and Arora, 1981).

(c) Chicks

Panda et al., (1975) replaced maize by sal seed meal in chick diets at levels varying between 2.25 to 45%, and found an inverse relationship between sal seed meal level and body weight attained by the chicks.

Nayak, Tripathi and Mohanty (1967) substituted 2.4 to 5% of the maize with sal seed meal to feed chicks up to eight weeks of age, while Saxena (1967) substituted 5, 10, 15 and 20% of the maize up to 5 weeks of age. The results from both trials indicated depression in growth rate compared to the control diets.

(d) Pigs

Limited studies have also been undertaken on the effect of feeding the meal to pigs. Murty, Joshi and Agarwal (1969) used a 20% level of sal seed meal to replace maize and noted reduced live weight gain, N and P balance. Agarwal (1971) reported a drastic drop in live weight gain when maize or ragi was replaced by deoiled sal seed meal. Pathak and Ranjhan (1973) replaced 20 and 40% levels of maize by sal seed meal and found comparable growth performance. The concluded that during the finisher phase, the meal can be included to replace maize (Table 10).

(e) Conclusion

The studies on both ruminants and non-ruminants fed with sale seed meal demonstrated that they are definite limitations in this feed. With non-ruminants, there appears to be a consistent depression in live weight gain. The problem is clearly associated with a high tannin content in the meal, which is variable. Panda et al., (1969) reported that 60% of the tannins can be removed either by boiling for 30 minutes or soaking the material for 24 hours in water. Gandhi et al., (1975) found that 50% of the tannins can be removed with 30% acetone and 0.1 N NaOH. Wah, Sharma and

TABLE 10

THE PERFORMANCE OF GROWING PIGS ON DIETS WHERE DEOILED SAL SEED MEAL (DSM) REPLACED MAIZE IN INDIA

(Pathak and Ranjhan 1973)

Parameter	Treatments		
	50% M, 0% DSM (Control)	20% M* 20% DSM	40% DSM 0% M
Daily live weight gain (kg)	0.46	0.45	0.46
Feed intake/day (kg)	2.9	3.1	3.2
Feed efficiency (kg feed/ kg live weight gain)	6.3	7.0	7.0

*M - Maize

DSM - deoiled sal seed meal

Jackson (1977) inactivated the tannins by 5 g Ca $(OH)_2$/100 g meal. Sharma, Wah and Jackson (1977) found however, that Ca $(OH)_2$ treatment was deleterious to goats and chicks, probably because of the breakdown of the calcium-tannin complexes in the alimentary canal to release the tannins. Singh and Arora (1978) found that 30% acetone or 1.0 N NaOH was more effective than 40% ethanol, water at 100°C and 3% salt solution. Although these methods have been used with varying degrees of success, it would appear that an effective practical method that can remove most of the tannins is yet to be demonstrated. Much will also depend on cost of the treatments. Until a practical and economic method can be achieved, reduced performance or other deleterious effects, will continue to govern the utilization of sal seed meal. The problem is likely to be more critical with non-ruminants than ruminants. With ruminants, the presence of tannins would reduce hydrolysis by rumen microorganisms, thus making the protein more available duodenally.

(vi) Tamarind Seed Hulls

Another by-product which is available in abundant quantities is tamarind (*Tamarindus indicus*) seeds. The seeds contain 30-45% red hulls and 60-65% white kernel. The hulls and kernels have about 9.1 and 15.4% crude protein and 11.3 and 1.5% crude fibre respectively. The seed hulls are palatable and can replace 10-15% of maize in the concentrate mixture of crossbred calves. It is estimated that 0.50-0.70 million tons of the material is produced in India.

In addition, it appears that hulls rich in tannins (13 to 15%) helped in improved utilization of the groundnut cake component of the ration, perhaps forming a protective coat for groundnut protein. Kernels on the other hand can replace 95% of the maize component of concentrate mixture (Reddy and Reddy, 1978), in growing cross-bred calves. Rangnekar (1978) fed crossbred bullocks with 1.5 kg tamarind seed powder as the sole source of concentrate and *ad libitum* sorghum straw for a preliminary period of three weeks, after which a metabolism trial was conducted. Digestibility coefficients and nitrogen balance were calculated by the different methods and are presented in (Appendix 2, table 7). The DCP and TDN contents of tamarind seed were 1.256 and 63.9 % respectively.

The nutritive value of tamarind seed hulls has been reported by Reddy, Reddy and Reddy (1979). Up to 15% levels gave a positive N, Ca and P balance. The material was used at levels of 0, 10 and 15% replacing maize in the experimental diets. The level of groundnut cake was held constant at 30%. Although the intake was similar for all treatments, there was a significantly high (P/0.05) faecal excretion of nitrogen with 15% tamarind seed hulls. This suggests that nitrogen digestibility was suppressed and it is distinctly possible that the presence of tannins influenced this. On the other hand, urinary nitrogen decreased, and it is also possible that the tannins contributed towards improved utilization of the nitrogen in groundnut cake. Clearly, the efficiency of utilization of dietary protein is influenced considerably by the tannins present, and not enough is known presently about the interaction between these and nitrogen in the animal body. More recently, tamarind seed powder (decorticated) has been fed to calves and it has been reported that on optimum level of 20% inclusion gave a daily gain of 828 g (Ann. Rpt., I.C.A.R., 1983).

3.4.2 Animal Proteins

(i) Blood Meal

Blood meal is a by-product from abattoirs. Much of it is wasted, but where it can be processed, it is a valuable protein source for animals. It is usually made by coagulating the blood by steaming or by boiling, collecting the coagulates then drying and milling.

In Malaysia, blood meal was included in diets for growing pigs, substituting fish meal at 0, 3, 6, 9, 12 and 15% levels and it was found that there were no significant differences between treatments. It was suggested, based on growth rate and feed efficiency data that a 3% level of blood meal was optimum in diets for pigs (Hew and Devendra, 1977).

(ii) Feather Meal

Feather meal is a by-product of poultry processing. Since feathers are not digested by simple stomach animals, they have to be hydrolysed at high temperature under sufficient pressure if a highly digestible product is to be obtained. The product has good keeping quality. It is rich in glycine, cystine, phenylalanine, but deficient in methionine, lysine, histidine and tryptophan. It therefore requires to be balanced with synthetic amino acids. Hydrolysis however, can only be justified when it has been proven to be economic.

A number of studies have been reported on their utilization notably in Thailand. In turkey poult diets, Balloun and Khajarern (1974) demostrated that 5 to 10% levels of the meal fed to chicks from one to eight weeks of age gave good results. With poultry, Khajarern et al., (1978) used 0, 2, 4, 6 and 8% levels of the meal replacing soyabean meal and found no significant effects on live weight gain, feed efficiency or dressing percentage in broilers. Pigs fed with 0, 5.2 to 10.4% level of the meal, substituting soyabean meal showed that the 5.2% level gave as good performance as those in the control group (Khajarern and Khajarern, 1977).

(iii) Poultry Excreta

Poultry excreta or manure, consists of the dry excreta, and the feathers and broken eggs that drop into beneath the poultry cages. It is available in large quantities in Pakistan, India, Thailand, Malaysia and Singapore. It is a useful manure for crop cultivation. It can also be used as a valuable feedstuff and considerable potential exists to incorporate it in the diet of farm livestock. Research on this subject demonstrates the practical and economical interest of this material (Mueller, 1979).

The total volume of poultry excreta produced in the Region is quite considerable. Table 11 shows the approximate amounts produced in individual countries. The equivalent total amounts of crude protein (N x 6.25) and total digestible nutrients (TDN) produced were 3,176 and 9,726 million kg respectively, which are potentially very valuable for feeding animals.

Poultry excreta is of two main types: that obtained from caged layers and from deep litter. The former is more uniform and suited to non-ruminants. The latter is contaminated with other materials such as wood shavings which makes it more suited to ruminants. In the litter from caged layers approximately 30% is true protein and the remainder uric acid.

- For Non-Ruminants:

Poultry excreta has been demonstrated by several workers to be useful in poultry diets (Wehunt, Fuller and Edwards, 1960; Yoshida and Hoshii, 1968; Shannon, Blair and D'Mello, 1969; Bieely _et al_., 1972; Lee and Blair, 1973; Ng and Hutagalung, 1974). There are also many reports of its use in the diet of ruminants (Noland, Ford and Ray, 1955; Southwell, Hale and McCormick, 1958; Bhattacharya and Fontenot, 1965; Fontenot _et al_., 1972; El-Sabban _et al_., 1970; Preston, Willis and Elias, 1970; Anthony, 1971; Bucholtz _et al_., 1971; Bull and Reid, 1971; Meenawat and Sharma, 1973). Only relatively low levels (up to 10%) are used in non-ruminant feeding whereas higher levels are used in diets for ruminants.

- For Ruminants:

The value of poultry excreta to the ruminant is enhanced by the fact that uric acid, the main source of nitrogen in the manure, is degrated to ammonia relatively slowly in the rumen, with little or no problem of ammonia toxicity. Consequently, it has been essentially used as a source of non-protein nitrogen (NPN) in the diet of sheep (Noland, Ford and Ray, 1955), beef cattle (Southwell _et al_., 1958; Fontenot _et al_., 1963); Bhattacharya and Fontenot, 1965; Preston, Willis and Elias, 1970) and dairy cattle (Maneewat and Sharma, 1973). Half of the crude protein appears to be made up of true protein which is high in glycine but low in arginine, lysine, methionine and cystine (Bhattacharya and Fontenot, 1966), uric acid constitutes approximately half the total NPN present in the litter. The content of amino acids is variable and is determined largely by the type of poultry litter. It is also useful as a source of energy (Bhattacharya and Fontenot, 1966), and also of calcium and phosphorus. Bhattacharya and Fontenot (1966) have suggested the need to supplement it with vitamin A, D and E.

The author studied the digestibility and utilization of poultry excreta with dietary levels of 0, 10, 20, 30 and 40% in molasses-based iso-nitrogenous diets fed to sheep. The crude protein content was 24.2%, being similar to that reported by Flegal

TABLE 11

ESTIMATED ANNUAL PRODUCTION OF NUTRIENTS IN POULTRY EXCRETA IN THE ASIAN AND PACIFIC REGION (on DM basis)*

Country **	Million kilograms per year			
	Poultry excreta production	Organic matter	Crude protein (N x 6.25)	TDN
Bangladesh	495.0	360.0	120.0	367.5
Burma	198.0	144.0	48.0	147.0
China	7550.4	5491.2	1830.4	5605.6
India	990.0	120.0	240.0	735.0
Indonesia	1122.0	816.0	172.0	833.0
Kampuchea	26.4	19.2	6.4	19.6
Korea Rep.	310.2	225.6	75.2	230.3
Laos	39.6	28.8	9.6	29.4
Malaysia	514.8	374.4	124.8	382.2
Nepal	158.4	115.2	38.4	117.6
Pakistan	475.2	345.6	115.2	352.8
Philippines	409.2	297.6	99.2	303.8
Sri Lanka	39.6	28.8	9.6	29.4
Thailand	429.0	312.0	104.0	318.5
Vietnam	330.0	240.0	80.0	245.0
Fiji	6.6	4.8	1.6	4.9
Papua New Guinea	6.6	4.8	1.6	4.9
Total	13,101.0	9,528.0	3,176.0	9,726.5

* Based on an annual production of 90 g of faeces/bird/day equivalent to 6.6 kg dry matter/bird/yr, 4.8 kg organic matter/bird/yr, 1.6 kg crude protein (N x 6.25) bird/yr and 4.9 kg TDN/bird/yr.

** Calculations were based on populations of chickens according to FAO (1982).

and Zindel (1970) but lower than the values of 31-34.3% reported by Fontenot et al., (1971), Bieely et al., (1972) and McNab, Shannon and Blair (1974). The Ca and P contents were high than those of McNab, Shannon and Blair (1974), but lower than those of Bieely et al., (1972) and Flegal and Zindel (1970). The gross energy was 9.2 (MJ/Kg), equivalent to about 2.2 Mcal/Kg. It was found that 20 to 30% levels are optimal for the utilization of poultry excreta in molasses-based diet.

However, 10% molasses has been reported optimal in diets for steers given 25 or 50% litter (Harmon, Fontenot and Webb, 1972) or with 30% unprocessed screened wood shaving broiler litter (Bhattacharya, Abu-Izeddin and Schwulst, 1971). In feeding trials with fattening steers, it was shown (Fontenot et al., 1963) that a diet containing 25% peanut-hull litter gave the best live weight gain and a feed efficiency that was higher than those fed with conventional fattening mixture containing soyabean meal as the protein supplement. The 30% litter ration was found to give a poor feed efficiency and a higher feed cost per unit of live weight gain. More recently, a 25% level of poultry litter has also been found to be suitable in the performance of dairy cattle (Maneewat and Sharma, 1973).

Further support for the suitability of an optimal level of 20 to 30% inclusion of poultry excreta in the diet comes from the studies of Bhattacharya and Fontenot (1966). These authors noted that when the litter level was increased from 25 to 50% the apparent digestibility of dry matter, nitrogen-free extract and energy decreased. The apparent digestibility of crude protein also decreased with increase in litter nitrogen level above 25%.

An optimal level of not more than 20 to 30% poultry excreta in the ruminant diet is also justified by the fact that the quality of poultry excreta is variable, and more important, it is not very palatable. With higher levels of feeding therefore (about 30% of the diet), a decreased dry matter intake is likely and can be associated with poor performance. Thus, in practical feeding trials with beef cattle where poultry waste represented 47.0, 62.0 and 69.0% of the total diet (Preston, Willis and Elias, 1970), the daily gain in live weight of Brown Swiss x Brahman cattle were 0.76, 0.69 and 0.63 kg, and the feed conversion 28.9, 35.4 and 40.2 Mcal ME/kg gain.

Fontenot et al., (1972) reported in long term studies with pregnant ewes fed 0, 25 and 50% broiler litter that all three diets produced equal body weights until the end lactation, and the number of lambs born per ewe and the birth weight of lambs were not affected by any dietary level of litter. High levels of between 75 to 79% litter has been used satisfactorily for milk production (Muftic et al., 1967; 1969b). In Thailand, Tinnimit (1977) has demonstrated the value of poultry litter compared to soyabean meal in diets for lactating cattle in Thailand (Table 12).

TABLE 12

RESPONSE OF LACTATING COWS FED POULTRY EXCRETA IN THAILAND

(Each value is the mean of six animals)
(Tinnimit, 1977)

Parameter	Control (Soya bean meal)	Treatment (Poultry excreta)
Grain consumed (kg/day)	7.8	7.3
Silage consumed (kg/day)	26.0	34.8
Body weight change (kg/day)	+0.95	+0.58
Milk yield (kg/day)	19.6	20.6
Butter fat (%)	3.30	3.87

It was found in the studies reported in Malaysia (Appendix 2, Table 8) that crude protein digestibility decreased with increasing inclusion of poultry excreta, and that the nitrogen in diets with poultry manure was not efficiently utilized. This may have been due to increased nitrogen lost in the urine a fact that has been noted in diets with a high content of urea (Huber et al., 1967; Razdan et al., 1971; Devendra, 1976b).

One practical problem for attention is the considerable variability in litter material used viz. wood shavings, saw dust, rice straw, bagasse, soil and storage time of the wet manure (Flegal, Sheppard and Dorn, 1972). Usually, it is advisable to use only the top 10-15 cm of the accumulated litter. The litter is best fed dry (after any stray metals or wire have been removed) and pulverized in a hammer mill. Also, since palatability is an important factor in the utilization of poultry excreta, this can be overcome by the use of molasses.

Part of the variability, and possibly also the palatability in poultry manure can be removed by steam heating (Noland et al., 1955) heat treatment (Bhattacharya and Fontenot, 1966) and hydrolysing or cooking (Bratzler and Long, 1968). These processes appear to be beneficial, since Brazler and Long (1968) for example have demonstrated that lambs given soyabean meal, hydrolysed and cooked poultry waste gave nitrogen digestibilities of 74, 66 and 69% and daily nitrogen retentions of 0.6, 0.9 and 1.1 g respectively. These possibilities merit further consideration and also economic evaluation.

In India, Parthasarthy and Prasad (1976) fed the autoclaved litter of laying hens after mixing it with groundnut hulls to crossbred bull calves and suggested that the optimum level of poultry litter in the ration should be only 10%. Jayal and Mishra (1969) replaced 50 and 100% groundnut cake with poultry litter in the ration of cattle but found it inferior to groundnut cake. Kishan and Husain (1977) fed dried poultry excreta to Hariana calves at 15 and 30% levels to replace part of the protein requirements, but did not find any significant differences as compared to control group.

More recently, various types of poultry litter have been fed to broilers. The treatments were poultry litter, autoclaved poultry litter and Pleorotus fermented poultry litter. The results of the growth trial over eight weeks indicated that 15% untreated poultry litter and 20% Pleorotus treated poultry litter could be used successfully to replace 7.5 and 100% of the groundnut meal in the diet. It was also observed that for each 5.0% inclusion of poultry litter, the mineral supplement in such rations could be reduced by 0.5% without affecting growth (Ann. Rpt., I.C.A.R., 1983).

Attempts have also been made to enasile poultry manure with grass hay at a 60:40 ratio, and a daily gain of 1 kg/animal has been reported in calves (Saylor and Long, 1974). Similarly in Malaysia, poultry litter has been successfully fed when ensiled with pineapple waste in feed lot diets for cattle (Mueller, 1978).

In recent years, considerable research and development effort has been directed in Pakistan at increasing the use of poultry litter especially in diets for ruminants. The two principal advantages that have been demonstrated are, firstly, potential increased use of an available feed, and secondly, substantial reduction in the cost of milk production when the diet is formulated from mainly local feeds. Table 13 demonstrates this point.

Based on the experience in Pakistan, it is relevant to draw attention to the following issues (Iqbal, Shal and Mueller, 1983):

(i) Prior to feeding, poultry litter should be ensiled, stacked, dehydrated or treated with chemicals or otherwise, to reduce the microbial count and totally eliminate pathogens;

(ii) Poultry litter can be fed to different classes of animals as follows:

a) Up to 30% DM in the ration (4-6 kg DM/head/day) for high producing dairy cattle. Higher levels of about 45% are possible for brief periods when feeds are in short supply.

b) Up to 40% DM in the ration for beef cattle. However, not more than 30% is recommended.

c) Up to also 30% DM for fat lambs, but the copper content in poultry litter may limit the level of the litter below 30%.

(iii) High energy feed ingredients molasses, root crops, grain, etc.) are necessary when large (25% DM and above of poultry litter) are used to ensure maximum utilisation of the non-protein nitrogenous component of the litter.

(iv) Palatability problems are best overcome by ensiling or chemical treatment. Molasses inclusion increases the palatability and intake of the litter. A dust-free ration prevents irritation of the eyes and the respiratory system.

(v) Adaptation to the feed is important and must be done gradually (3-5 days).

(vi) When fed at or about the 20% level, poultry litter usually supplies all the calcium and phosphorous requirements.

TABLE 13

ECONOMIC ADVANTAGE OF FEEDING POULTRY LITTER IN DIETS FOR MILK PRODUCTION IN PAKISTAN (Hasnain, 1983)

Item	Unit	Treaditional feeding	Diet with 30% poultry litter
Feed cost/head/day	Rs.	14.34	8.50
Feed cost/head/90 days	Rs.	1296.80	765.00
Av. milk yield/head/day	Litre	6.76	7.28
Feed overheads	Rs/litre	2.12	1.17
Income from milk/head*	Rs.	21.97	23.40
Income over feed cost	Rs.	7.63	14.90
Difference in income/head/day	Rs.	--	7.27
Feed saving over 90 days/head	Rs.	--	654.30
Feed saving over 300 days/head	Rs.	--	2181.00

* 1 litre of milk costs 3.25 Rs.

(vii) The critical constituent of poultry litter is ash which reduces the amount of organic matter in the total ration and adds to the total content of indigestibles.

(viii) Poultry litter containing high levels of antibiotics and other anti-microbials and chemotherapeutics should be avoided.

The need to increase the utilization of poultry excreta in the Region is justified on two grounds. Firstly, the cost of imported supplements, such as groundnut cake or fish meal are expensive and in short supply. They thus contribute towards a high cost of feeding. Secondly, the efficient utilization of poultry excreta, abundantly available from the large poultry industries in the Region, will be an effective means of recycling a waste material which could also be a pollutant.

(iv) Poultry Waste Meal

In addition to feather meal, there is another by-product produced from poultry processing. This is referred to as poultry by-product meal and consists of the products after dry rendering of the feet, head and intestines. This is also a valuable protein source, and its value in diets for farm animals has not been adequately studied.

3.5 Leaves of Field and Tree Crops

3.5.1 Leaves of Field Crops

Leaves from field and tree crops are important non-conventional feedstuffs that are extensively used for feeding ruminants, especially in Pakistan, India, Bangladesh and Indonesia. A discussion of some of the more important ones is therefore relevant.

(i) Banana Leaves (*Musa* *spp*.)

Banana leaves are very commonly fed to ruminants, especially goats, throughout the Region. Usually, the leaves are fed when the trees are chopped following fruit harvesting. With goats however, there is a conscious attempt to harvest the leaves wherever this is available such as in India, Pakistan, the Philippines, Sri Lanka, Malaysia and Indonesia. The leaves are palatable, have a relatively high crude protein content and have laxative properties.

In India, banana leaves have been fed to Red Sindhi bulls. The animals relished the leaves but diarrhoea was apparent within a week when only the leaves were fed. However, when fed with rice straw and some protein cake, the average total dry matter consumption was increased to 1.82 kg/100 kg live weight and digestive problems were uncommon. The DCP and TDN contents of the total ration were 3.9% and 54.9%, respectively, and N, Ca, P and Mg balance were postive (Gupta, Singh and Gupta, 1976). The DCP of banana stems is inferior to that of banana leaves (Johari and Nuriddin, 1967).

(ii) Cassava (Manihot esculenta Crantz) leaves

Cassava leaves are emerging to be a valuable feedstuffs. They have not been utilized to any great extent in the past because of the presence of polyphenol inhibitors, cyanogenic glucosides and tannins which are toxic. But this depends on the variety used, since higher levels of HCN are found in the "bitter" varieties. Figure 2 illustrates the approximate amounts of products and by-products that are available from the mature cassava plant.

The lack of interest in the leaves is associated with four reasons (Devendra, 1977a): (1) decreased root yields due to harvesting the leaves, (2) relatively low yield during harvesting at maturity, (3) possibilities of HCN toxicity especially with bitter varieties, and (4) inadequate appreciation of the presence in the leaves of a relatively high crude protein content.

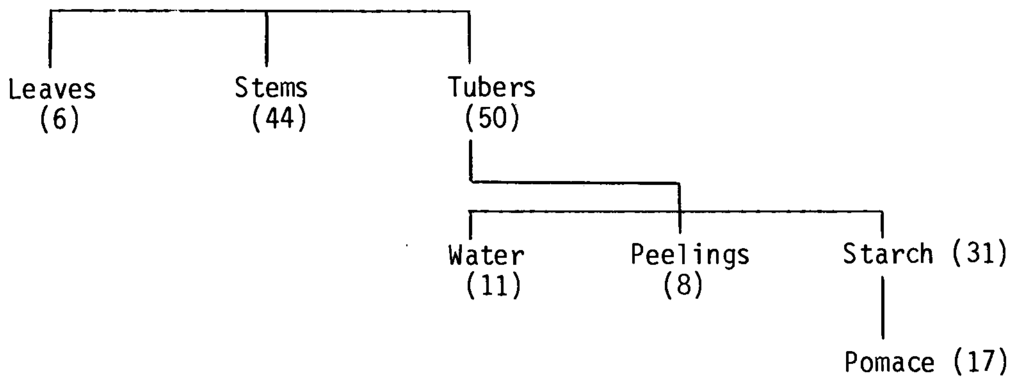
Moore (1976) was the first to report from studies with beef cattle the potential value of the aerial part of cassava in sugarcane based diets in Colombia, and demonstrated that when planted at a high population density, repeated three to four month cutting intervals are feasible over a total growing period of up to 18 months.

The escalating prices of feed ingredients especially of preformed proteins, and the need to ensure that there are adequate "by-pass" proteins than can supplement rumen microbial proteins for production (Leng and Preston, 1976), have let to attention being directed to cassava leaves as a potential source of proteins (see for example Meyrelles, Macleod and Preston, 1977a). The potential value of these leaves has stimulated much research in the ruminant (Alvarez, et al., 1977; Meyrelles, Macleod and Preston, 1977b, 1977c). Cassava leaves have however, been fed to calves in Africa (Guin and Andouard, 1910), cattle in Cuba (Osvaldo, 1966) and Madagascar (Serres, 1969) and as a dry season supplement in Brazil (Gramacho, 1973). The value of leaves in promoting increased growth response in cattle has also been demonstrated in Santo Domingo (Meyrelles and Fernandez, 1978). Montaldo (1977) reported on the use of the whole cassava plants as feed for ruminants in Venezuela.

Cassava leaves are also a potential source of low cost protein, and have been used as a source of proteins for humans (Terra, 1964). Cassava leaves were reported to contain large quantities of essential amino acids in an assessment of 23 plant types (Hall, Nagy and Berry, 1975). They also have a high carotene content. The lysine content is high and methionine level low (Oke, 1973). Cassava leaves can therefore be used to supplement cereal diets that may be deficient in lysine.

FIGURE 2

APPROXIMATE AMOUNTS OF PRINCIPAL PRODUCTS AND BY-PRODUCTS IN THE WHOLE CASSAVA PLANT AT MATURITY (12 months)+



\+ Figures in parentheses refer to approximate proportions, expressed as per cent of the original cassava plant.

Table 14 presents data on 11 varieties of cassava leaves both "bitter" and "sweet" in Malaysia. Of these, variety C5 was used in digestibility studies and it was found to contain 14.5% DCP, 49.6% TDN, 100 MH/Kg of ME and a biological value of 65.4% N and Mg balance was positive, but Ca and P balance was negative (Appendix 2, Table 9).

The value of vassava leaves as a protein source is seen especially in situations where dietary nitrogen is limiting, such as when low quality roughes are fed, is seen in Table 15. Substituting untreated rice straw with cassava leaves with about 33% of cassava leaves increased DMI by about 34-37%, and was associated with statistically significant differences ($P<0.05$) in organic matter, crude protein, crude fibre digestibilities and N retention.

Support for these findings comes from the results of feeding trials in Indonesia (Table 16). The inclusion of up to 50% cassava leaves with treated or untreated rice straw stimulated live weight gain, but treatment effects were not significant. It was concluded th t grinding and urea-ammonia treatments of rice straw enabled goats to maintain weight, however, the inclusion of cassava leaves enabled pelleting of the feeds and for goats to gain weight. In Thailand, feeding other untreated rice straw, urea-ensiled rice straw or urea-ensiled rice straw plus 280 g/head/day of dried cassava leaves to yearling buffalo steers significantly affected ($P<0.05$) live weight gain, with responses of -383, 136 and 182 g/head/day respectively (Wanapat, Praserdsuk and Chanthai, 1983).

(iii) Gliricidia (*Gliricidia maculata*) leaves

Gliricidia leaves are useful fodder for ruminants and have been used extensively especially in Sri Lanka for buffaloes and cattle. It has been shown that supplementation with coconut cake significantly increased both milk yield and fat yield ($P<0.05$), whereas th leaves did not affect both components. In an earlier study however, Perdok *et al.*, (1982), reported results with the same herd that supplementing with 1600 g gliricidia (DM/cow/day) increased both milk and milk fat yields. Supplementing the treated straw with gliricidia or leucaena in addition to coconut cake did not have any significant effect on milk yield and milk fat yields. An economic analysis of the profit margin due to treatments indicated (Table 17) that supplements of tree legumes marginally improved milk and milk fat yields, but was considerably improved by supplementation with 7 kg coconut cake.

(iv) Ipil-Ipil (*Leucaena leucocephala*)

This tropical legume is becoming increasingly popular in the Region and elsewhere as a very valuable forage. Its value as a supplement has been demonstrated in a number of situations (Siebert, Hunter and Jones, 1976; Thomas and Addy, 1977; Alvarez, Wilson and Preston, 1977; Flores-Ramos, 1979; Yates and Lowry, 1982;

TABLE 14

THE CHEMICAL COMPOSITION AND MINERAL CONTENT OF CASSAVA
(MANIHOT ESCULENTA CRANTZ) LEAVES IN MALAYSIA
(% dry matter basis)
(Devendra, 1978a)

Variety	DD.N.	C.P.	C.F.	E.E.	ASN	N.F.E.	G.E. MJ/Kg	Ca %	P %	Mg %	Na %	K %	Mn ppn	Fe ppn	Cu ppn	Zn ppn
Black Twig*	24.1	23.8	14.0	2.8	5.7	53.7	15.6	0.91	0.14	0.32	0.05	1,25	83	4	4	21
Betavi (Borat)	16.2	22.2	8.9	3.7	5.3	59.9	19.3	1.01	0.19	0.32	0.05	0.49	116	3	7	66
Brazil 146 56/A*	22.9	25.0	20.5	2.6	3.2	48.7	19.5	0.53	0.09	0.22	0.05	0.54	43	8	7	16
C5*	25.0	23.2	22.2	5.0	6.2	43.4	20.9	1.25	0.07	0.13	0	1.93	48	41	13	67
Green Twig*	21.2	25.0	12.3	2.9	5.7	44.1	17.2	0.86	0.22	0.42	0.04	1.54	60	24	10	34
Jurai	27.4	24.1	23.2	1.3	2.5	48.9	22.8	0.61	0.11	0.17	0.04	0.59	37	15	8	19
Llanera	26.6	21.2	8.7	3.9	5.0	61.2	18.9	0.81	0.26	0.23	0.03	1.47	63	8	8	39
Madan (kekalu)	25.5	22.7	9.7	3.6	5.3	48.7	16.7	0.63	0.07	0.25	0.07	1.19	20	3	11	22
Ubi Putch I	23.3	23.5	9.4	3.1	5.4	58.6	17.2	0.55	0.20	0.28	0.07	1.22	40	7	9	30
Ubi Putch II	22.7	24.0	9.2	2.6	5.5	58.7	16.4	0.78	0.25	0.29	0.07	1.38	45	26	10	32
Ubi Ladang (Batang Putch)	21.7	22.6	8.1	2.9	6.0	60.4	16.8	0.98	0.20	0.48	0.07	1.57	66	14	11	46

* Bitter varieties

TABLE 15

INTAKE AND DIGESTIBILITY OF LONG OR CHOPPED RICE STRAW (RS) SUPPLEMENTED WITH OR WITHOUT CASSAVA LEAVES (DEVENDRA, 1983c)

Parameter	Long RS	Chopped RS	Long RS + CL*	Chopped RS + CL
Fresh Intake (g/day)	626.4a*	633.6a	1692.0b	1640.9b
DMI/kg$^{0.75}$(g/day)	50.7a	49.7a	70.1b	67.4b
DMI as % Body weight (%)	2.6a	2.3a	3.2b	3.1b
DM digestibility (%)	46.4a	41.3a	53.0a	49.8a
OM digestibility (%)	51.1a	47.2a	61.4b	54.2a
CP digestibility (%)	18.3a	31.4b	64.7c	62.4c
Energy digestibility (%)	48.4a	42.4a	55.5a	51.1a
N retention as % of Intake (%)	-43.3a	22.8b	58.4b	43.6c

\+ Cassava leaves

* Significant differences (P<0.05) between means with columns are indicated by dissimilar superscripts (a, b, c).

TABLE 16

EFFECT OF FEEDING UNTREATED AND UREA-AMMONIA TREATED GRADE RICE STRAW ON THE AVERAGE DAILY GAIN OF YOUNG GOATS (WINUGROHO and CHANIAGO, 1983)

Treatment+	Live weight gain (g/day)	
	9 weeks	13 weeks
75 URS : 25 CL	53^{b*}	45^{b}
50 URS : 50 CL	91^{a}	92^{b}
75 TRS : 25 CL	93^{a}	84^{a}
50 TRS : 50 CL	105^{a}	101^{a}
100 TRS	11^{c}	27^{b}
S.E.	10.3	10.4

\+ URS - Untreated rice straw, TRS - Treated rice straw, CL - Cassava leaves.

* Significant differences (P/0.05) between means within columns are indicated by dissimilar superscripts (a, b, c).

TABLE 17

THE EFFECT OF FEEDING UREA-AMMONIA TREATED STRAW WITH SUPPLEMENTS TO LACTATING SURTI BUFFALOES (ADAPTED FROM PERDOK *et al.*, 1983)

Parameter	TRS	Treatment[+]				
		TRS + G (212 CP)[++]	TRS + L (251 CP)	TRS + CC (191 CP)	TRS + G + CC (406 CP)	TRS + L + CC (448 CP)
Milk yield (kg/day)	2.41C*	2.60c	2.73bc	3.09ab	3.18a	3.36a
Milk fat yield (g/day)	221b	242b	238b	311a	319a	325a
Milk fat percentage (%)	9.18	9.34	8.71	10.08	10.03	9.65
Margin over costs (S.L. - RS)	4.07	5.19	4.57	8.34	8.52	8.53

\+ TRS-Urea-ammonia treated rice straw; G - gliricidia; L - Leucaena; CC - Coconut cake

++ Amount of crude protein provided

* Significant differences (P/0.05) between means are indicated by dissimilar superscripts (a, b, c, d, e).

Devendra, 1983c). There are also several recent reviews relating to the use of leucaena in animal production (Jones, 1979; I.D.R.C., 1983).

One main constraint to its feeding value is the presence of the toxic amino acid mimosine, and its breakdown product in the rumen DHP (3-dehydroxy-H pyridone); tannins are also found in leucaena. Sheep unaccustomed to feeding leucaena, shed their wool between 7 and 14 days after leucaena feeding commences. Adaptation to leucaena diets is important to enable the rumen microorganisms to break down the mimosine as it increases. Goats fed mimosine have been shown to degrade the mimosine content from 60 to 0.3 mmg/g after 25 hours, and with pure mimosine, 98% was degraded by the rumen fluid after five hours (Shiroma and Akeshi, 1976). In India, feeding the forage to adult Barbari goats over 33 days indicated that falling of hair was only noted in one animal during the last week. The mean intake was 2.16 kg/100 kg of live weight, and the DCP and TDN contents were 16.7% and 70.2% respectively. The goats were in positive N and Ca balance. The leaves alone were inadequate to meet the energy requirements for maintenance (Upadhay, Rekib and Pathak, 1974). The nutritive value for goats has been reported to be 16.7% DCP and 70.2% TDN (Upadhay et al., 1974). In the Philippines, ipil-ipil has been used to supplement rice straw for cattle (Perez, 1976).

There is evidence that there are adaptational differences to the level of feeding leucaena. In some countries such as in Australia, ruminants develop signs of toxicity when they consume a high proportion of leucaena in the diet, whereas animals in other countries such as in Indonesia, Philippines and Hawaii do not. The reason for this difference appear to be related to the ability to degrade mimosine and DHP. Among the ruminants, goats in particular, appear to do this move efficiently, and consequently are able to utilise higher levels of the forage. There is also evidence that goats are unaffected (Kranveld and Djaenoedin, 1947; Owen, 1958; Jones, 1981).

In Malaysia, increasing levels of leucaena forage for substituting untreated rice straw (0-60%) was associated with increased ME intake, crude protein and energy digestibilities and N retention. The increased ME intake ranged from 16.2% to 86.2% for the 10 and 50% levels of leucaena inclusion respectively (Table 18). The economic advantage of using leucaena in diets for cattle is reflected in the study of Trung et al. (1983). Table 19 demonstrates that the cost/kg live weight gain in the backyard system of 4.61, 4.42 and 4.26 P for diets 1, 2 and 3 is much lower compared to 10.33 P for diet 4 where up to 65% concentrates were used. One other important advantage of using leucaena is that supplementation increases the availability of Ca, Mg and P (Moran, Satoto and Dawson, 1982).

The comparative feeding value of either cassava leaves (CL), leucaena leaves (L), leucaena leaves plus stems plus pods (LSP) or gliricidia leaves (G) has also been studied when substituted 30% untreated rice straw fed fresh to sheep. While all forages increased

TABLE 18

INTAKE AND DIGESTIBILITY OF CHOPPED RICE STRAW (RS) SUPPLEMENTED WITH VARYING LEVELS OF LEUCAENA LEAVES

(DEVENDRA, 1983c)

Parameter	RS+ (control)	RS+ 10% L ++	RS+ 20% L	RS+ 30% L	RS+ 40% L	RS+ 50% L	RS+ 60% L
Fresh Intake (g/day)	741.3a*	890.7ab	967.7ab	1158.7ab	1446.0bc	1475.7bc	1300.7bc
DMI/kg$^{0.75}$ (g/day)	59.9a	58.9a	53.2a	59.9a	68.5b	70.7b	59.9a
DMI as % Body weight (%)	2.7a	2.6a	2.6a	2.8a	3.1a	3.1a	2.7a
DM digestibility (%)	42.4a	48.5b	46.7b	49.5b	50.5b	53.2c	49.6b
OM digestibility (%)	50.9a	51.3a	49.5a	52.5b	53.3b	55.5b	52.4b
CP digestibility (%)	19.7a	40.5a	47.2c	49.6c	52.0c	66.2d	50.5c
Energy digestibility (%)	40.4a	46.4b	46.3b	52.1c	51.5c	54.7c	46.2b
N retention as % of Intake (%)	- 0.1a	20.2b	16.4b	23.6b	31.5c	27.5c	30.8c

++ RS - rice straw; L - leucaena leaves

* Significant differences (P/0.05) between means are indicated by dissimilar superscripts (a, b, c).

TABLE 19

EFFECT OF FEEDING RICE STRAW DIETS SUPPLEMENTED WITH LEUCAENA LEUCOCEPHALA AND/OR DRIED POULTRY MANURE TO CROSSBRED DAIRY HEIFERS IN THE PHILIPPINES

(adapted from Trung *et al*., 1983)

Parameter	Treatments			
	1	2	3	4
Average daily gain (kg)	0.58a*	0.44a	0.53a	0.50a
Feed efficiency (kg)	15.6a	25.2a	15.2a	11.9a
Final weight (kg)	307a	241b	258b	272ab
Daily feed costs (P)				
Commercial+	8.41a	3.98c	4.89b	5.33b
Backyard++	2.63b	1.90b	2.22b	5.09a

Treatments : 1 - 35% Rice straw + 45% Leucaena + 25% concentrates

2 - 35% Rice straw + 30% Leucaena + 15% dried poultry manure + 20% concentrates

3 - 35% rice straw, 22.5% Leucaena, 22.5% dried poultry manure + 20% concentrates

4 - 35% rice straw + 65% concentrates

* Significant differences ($P \leq 0.05$) between means are indicated by dissimilar superscripts (a, b, c).

\+ 15 cows

++ 2 - 3 cows

the ME intake by 62.7, 67.4, 31.3 and 62.0% respectively, in terms of crude protein and N retention, the ranking order was leucaena leaves, cassava leaves, leucaena leaves plus pods and gliricidia leave- (Table 20). The higher N retention is consistent with the finding in Indonesia, that supplementing leucaena at 0.7 g DM/head/day increased microbial protein synthesis from 14 to 32 mg/100 ml/hr and rumen NH_3 levels from 9 to 12 mg/100 ml. Increasing leucaena to 1.5 kg DM/head/day reduced microbial protein synthesis to 25 mg/100 ml/hr (Hendrantno,1982). In Sri Lanka, Jayasuria, Wijeyatunge and Perera (1982) have reported that in terms of solubility of protein in the rumen and acid of pepsin at 8 hr, the forages used (other than spent tea leaf, rubber seed meal, fish meal and coconut oil meal), the lowest solubility was recorded by gliricidia leaf meal followed by leucaena leaf meal and then cassava leaf meal.

In most parts of the Region, leucaena is mainly fed fresh after harvesting, but the dried leaf meal is also available, such as in the Philippines, commercial production of leucaena leaf meal and especially detoxified leaf meal can stimulate increased use of the feed for non-ruminants in the Region. When used at the 5% level, it is estimated that the requirement for the feed in Indonesia, Malaysia, Philippines, Thailand and Singapore (ASEAN Regions) is about 405,000 mt, which is substantial.

The mimosine and tannin contents are presently a deterrent to the use of leucaena in poultry diets. The mimosine content can be treated with water at 60^{o}C to convert it to DHP. Mimosine and DHP can be destroyed by auto-claving at 120^{o}C after adding NaOH and macerating, but both methods are expensive and not practical. More recently, the problem has been resolved through the use of ferric sulphate (8.45 g/kg diet) and also polyetheleneglycol (PEG) is isoenergetic and isonitrogenous diets for poultry containing 150 g leucaena meal/kg. It has been reported that the combined supplements restored growth of leucaena-fed chicks to 90% of that obtained by birds fed a soyabean meal-maize control diet (Acamovic and D'Mello, 1984).

v) Jackfruit (*Artocarpus heterophyllus*) leaves

Jackfruit leaves are very extensively used for feeding cattle and sheep, and particularly goats in many countries in the tropics, notably Pakistan, India, Bangladesh, Malaysia and Indonesia. An assessment of nutritive value indicated a DCP and TDN content of 2.6% and 21.4% (Devasia, Thomas and Nandakumaran, 1976).

vi) Jhanji (*Scirpus articulatus*)

In Pakistan, India and Bangladesh, there is a common semi-aquatic plant which has some value for feeding to ruminants. It is found abundantly throughout West Bengal, Bihar and Orissa and Andhra Pradesh. Adult Sindhi bullocks have been found to consume 1.46 kg/100 kg body weight dry matter of jhanji which contains 9.31% DCP and 43.9% TDN (Gupta and Saha, 1977b). When Jhanji was fed with rice straw, the dry matter intake increased further to 2.33 kg/100 kg body weight.

TABLE 20

INTAKE AND DIGESTIBILITY OF CHOPPED RICE STRAW (RS) SUPPLEMENTED WITH EITHER CASSAVA LEAVES (CL), LEUCAENA LEAVES (L), LEUCAENA LEAVES PLUS STEMS PLUS PODS (LSP) OR GLIRICIDIA LEAVES (GL)

(Devendra, 1983c)

Parameter	RS+CL	RS+L	RS+LSP	RS+GL
Fresh Intake (g/day)	1556.8a*	1408.6a	1414.5a	1414.3a
DMI/kg$^{0.75}$(g/day)	65.9a	69.7a	64.7a	64.1a
DMI as % Body weight (%)	3.0a	3.2a	3.0a	2.7a
DM digestibility (%)	53.5a	49.2a	48.0a	47.6a
OM digestibility (%)	60.5b	56.9a	55.4a	55.4a
CP digestibility (%)	49.7b	50.4b	44.3b	31.6a
Energy digestibility (%)	54.7a	52.6a	45.7a	48.9a
N retention as % of Intake (%)	162d	34.8b	39c	92cd

* Significant differences (P/0.05) between means are indicated by dissimilar superscripts (a, b, c).

vii) Jute (Corchorus)

Although jute, (Corchorus) is cultivated mainly as a fibre crop in eastern India, it produced leaves that are useful to ruminants. Similar to cassava leaves which have a toxic HCN content depending on variety, the leaves of the Capsularies variety are "bitter" while those of the Ditorius variety are "sweet" and edible. Approximately 4,000 tonnes of dry jute leaves are available from West Bengal. Gupta, Gupta and Mathur (1972) have reported that adult Sindhi bullocks consumed 1.94 kg/ 100 kg body weight of dry matter and the digestibility coefficients were as follows: dry matter 49.8%, organic matter 54.3% crude protein 44.8% crude fibre 55.1% and nitrogen-free extract 55.0%. The DCP and TDN contents were 1.40 and 60.6% respectively Feeding Ditorius leave hay to Sindhi calves gave an average daily gain 500 g compared to 433 g per day for the control diet without the leaves (Gupta and Saha, 1977a).

viii) Pigeon pea leaves (Cajanus cajan)

Pigeon pea (Cajanus cajan) is a valuable legume useful for both human and animal nutrition. Although it is cultivated extensively in India, some countries in South East Asia, parts of Africa and the West Indies, it was introduced only recently from the latter into Malaysia and appears well suited to this country (Anon., 1977).

The principal product of the plant is seed which is used for human consumption. But the plant is also useful as a source of fodder especially to ruminants (Krause, 1932; Axtmayer, Hernandez and Cook, 1938; Kok, 1946; Llorens and Oliverei, 1957; Mills, 1961; and Schaaffhausen, 1965). Zebu cattle grazing on pangola grass/ pigeon pea grown gained an average of 29 kg in 93 days during a severe drought whereas cattle on the grass alone lost weight (Schaaffhausen, 1965). In Hawaii, it has been reported that the forage is not relished by cattle at the immature stage and grazing should be deferred to the early green-pod stage (Hosaka and Ripperton, 1944).

The nutritive value of C. cajan Cv. SS6 forage (leaves plus stems) harvested at 97 days age, has been determined fro balance trials using goats and sheep. The average weight of the leaves and stems were 500 and 482 kg/ha with leaves accounting for 55.5% and stems 44.5% of the total yield. No significant differences were noted between species in dry matter intake, but there were differen es (P/0.05) in the digestibility of dry and organic matter, crude fibre, ether extract, energy and N retention. The DCP, TDN and ME contents were 11.9% and 9.1%, 52.9% and 40.7% and 11.0 and 8.0 MJ/kg for goats and sheep respectively (Devendra and Chee, 1979). Table 21 summarises the results of this study.

TABLE 21

THE INTAKE AND DIGESTIBILITY OF PIGEON PEA FORAGE

(Devendra and Chee, 1979)
(Each value is the mean of 3 animals)

Parameter	Goats	Sheep	t-value
Mean dry matter intake (DMI/day,g)	314.9	304.0	NS
$DMI/w^{0.75}$ (g/day)	33.0	27.8	NS
Digestibility of dry matter (%)	53.5	46.2	3.72*
Digestibility of organic matter (%)	55.4	47.2	4.41*
Digestibility of crude protein (N x 6.25, %)	59.4	45.5	NS*
Digestibility of crude fibre (%)	61.8	43.2	3.45*
Energy	57.1	41.5	3.22*
N retention as % of daily N intake	54.4	-ve	*

*P /0.05

+ Not statistically significant

ix) Spent Tea Leaves

Spent tea leaves (STL) are by-products of the tea industry in Sri Lanka and India. STL contains approximately 30% crude protein in the dry matter. It has been shown that about 7% of the total DMI can be satisfactorily used as an N supplement for NaOH treated straw. It has been used successfully and without deleterious effects to both sheep and cattle and a saving of up to 25% in costs in concentrate diets incorporating STL has been reported (Jayasuriya, Panditharetne and Roberts, 1978).

The value of STL has been compared with six other protein sources (cassava leaf meal, gliricidia leaf meal, fish meal, leucaena leaf meal, rubber seed meal and coconut oil meal) using the nylon bag technique and subsequent acid pepsin digestion in vitro. STL showed the lowest protein disappearance rate and rumen solubility at 8 hr of fermentation. Polyphenols present in STL appear to offer protection to the protein and also reduce rumen fermentation, and it has been shown in this connection that STL appears to be a suitable feed for growing calves and milking animals (Jayasuriya, Wijeyatunge and Perera, 1982). In India, up to 20% level has been used in concentrate mixtures for Sindhi and Jersey calves which recorded a daily live weight gain of 370 g/day (Ann., Rpt., I.C.A.R., 1983).

x) Sun Hemp (Crotalaria Juncea)

Sun hemp leaves are valuable feeds. (Crotalaria juncea) is non-toxic (Katiyar and Ranjhan, 1969), but other varieties are toxic. Sun hemp is commonly cultivated for fibre production as a soil cover and also as a green manure. It contains 13.4% DCP and 58.9% TDN fed to sheep (Balaraman and Venkatakrishnan, 1974). The corresponding values for goats were 10.3% DCP and 44.6% TDN (Jayal and Johri, 1977), and for cattle 12.7% DCP and 66.0% TDN (Reddy and Murty, 1972). Sun hemp meal at an 8% level in chick diets was found to give maximum weight gains (Reddy, Rao and Subhan, 1970).

xi) Water Hyacinth (Eichornia Crassipes)

Water hyacinth is an aquatic plant and is found throughout the Region, notably in India, Bangladesh, Thailand, Malaysia and Indonesia. It grows rapidly and has tended to clog streams and ponds in areas where there is much surface water as in Bangladesh and Thailand.

The feed has been traditionally used especially by Chinese farmers, after cooking it, to feed pigs in the densely populated pig rearing areas of the Region as in Thailand and Malaysia. However, this use represents only a fraction of the water hyacinth used in this way.

The FAO Handbook on utilization of aquatic plants (1986) reviewed the methods of utilization of water hyacinth, including its use as an animal feed. In most parts of the Region, feeding water hyacinth has been fed mostly to pigs. In India, it has also been fed to cattle (Carbery et at., 1937; Chatterjee and Hye, 1938), but only in moderate quantities in combination with concentrates or other feeds. When fed fresh, cattle were found to suffer from diarrhoea (Hossain, 1959) and diuresis (Senkarmakar, and Kehar, 1955-56).

Gupta et al., (1975) fed water hyacinth hay to adult Sindhi cattle duly supplemented with groundnut cake and paddy straw without any signs of diuresis or diarrhoea. At an intake of 1.24 kg dry matter/100 kg live weight dry matter intake, there was a positive Ca and P balance. Live weight gain was 10 kg during a feeding period of 32 days, the DCP and TDN of the total ration being 7.0% and 46.9% respectively. Water hyacinth has also been made into silage with rice straw and fed to cattle without any deleterious effects (Senkarmakar and Kehar, 1955-56; Ray and Mudgal, 1968). Gupta et al., (1975) prepared silage from water hyacinth and rice straw mixed in a 4:1 ratio and containing 2% added common salt. The DCP and TDN of this silage were 5.64 and 40.2% respectively. Replacing 10 to 20% of the wheat bran in the diets of crossbred calves with water hyacinth gave comparable weight gains to those on the control diet (Reddy, and Reddy, 1979). Reddy and Mohan Rao (1979) have reported that there were no difference in digestibility between water hyacinth hay supplemented with either untreated rice straw or alkali treated straw in a 1:1 ratio. These diets also gave a positive N, Ca and P balance.

In Thailand, water hyacinth has recently been used in feeding trials with cattle and swamp buffaloes in urea-ammonia treated rice straw based diets. The treatments were untreated rice straw, urea treated rice straw (5% urea and 0.3% al w/w), urea treated rice straw with water hyacinth (3:1 ratio) and urea treated rice straw with water hyacinth (1:1 ratio). Over 110 days duration, the daily live weight gains were -34, 7, 133 and 23 g/day for cattle and -182, 79, 232 and 320 g/day for buffaloes respectively. It was concluded that a 25-50% level of water hyacinth was useful in diets for beneficial (Wanapat, Sriwattanasombat and Chanthai, 1983).

One problem with water hyacinth is that it contains about 2.5% oxalic acid. Little is known about the effects of this on metabolism and on the performance of animals.

3.5.2 Tree leaves

The feeding of tree leaves to ruminants has been traditionally practiced by small farmers for several decades. With small ruminants, an in particular with goats, feeding of a variety of leaves is standard husbandry practice. Goats relish variety in their diets and feeding tree leaves help to extend their diet preferences.

A number of different kinds of leaves are used in feeding, some more important than others. A list of the more important leaves from tree and field crops that are extensively used by goats and to a lesser extent by sheep in several countries in the Region is presented in Table 22. Several of these have been studied in India.

Mia *et al.*, (1960a) found that Bargad (*Ficus bengalensis*) leaves had nutrient values of 1.89% DCP and 44.53% TDN when fed to cattle and 4.1% DCP and 51.1% TDN when fed to goats. The corresponding figures for pipal (*Ficus religiosa*) leaves were 7.9% DCP and 40.4% TDN in cattle feeding and 7.6% DCP and 35.5% TDN when fed to cattle and goats (Mia *et al.*, 1960b). The feeding experiment on goats showed that gular (*Ficus glomerata*) leaves contained 6.7% DCP and 53.8% TDN (Majumdar and Momin, 1960). Jayal (1961) fed shisham (*Dalbergia sissoo*) leaves to Kumani bullocks and reported 9.1% DCP and 52.4% TDN. Gauj (*Milletia auriculata*) is a large woody climber found in the Himalayas and its leaves have been found to contain as much as 15.5% DCP and 44.9% TDN (Jayal and Sahai, 1960). Bamboo (*Dendrocalamus strictus*) leaves have been fed to goats and cattle in several countries in the Region, and Jayal (1963) have reported 9.34% DCP and 48.8% TDN. Mulberry (*Morus indica*) leaves has been reported to contain 10.7% DCP and 59.6% TDN (Jayal and Kehar, 1962). Digestibility studies with sheep fed ardu (*Ailanthus excelsa, Roxb*) tree leaves indicated that the feed contained 13.1% DCP and 63.1% TDN (Bhandari and Gupta, 1972). The utilization of tree leaves in the humid tropics region has recently been discussed (Devendra, 1983d).

TABLE 22

SOME IMPORTANT TREE LEAVES AND BROWSE PLANTS IN THE SOUTH EAST ASIAN REGION

Common Name	Botanical Name
I. Bangladesh, India and Pakistan	
Anjan	*Hardwickia binnata*
Ardu	*Ailanthus excelsa* Roxb
Babul	*Acacia arabica*
Bauhinia	*Bauhinia spp.*
Banana	*Musa spp.*
Bargad or Banyan	*Ficus bengalensis*
Beri	*Ziziyphus jujuba*
Dhaincha	*Seshania aculeaton*
Gular	*Ficus glomerata*
Imli	*Tamarindus indica*
Jackfruit	*Artocarpus heterophyllus*
Jamun	*Engeinia jambolana*
Kheiri	*Prosopis cineraria*
Khair	*Acacia catechu*
Khanthal	*Artocarpus integrifolia*
Mulberry	*Morus indica*
Pakar	*Ficus infectoria*
Pipal leaves	*Ficus religiosa*
Neem	*Azadirachta indica*
Sainjan	*Moringa oleifera*
Siras	*Albizzia lebbeck*
II. Indonesia, Malaysia, Philippines and Sri Lanka	
Banana	*Musa spp.*
Banyan	*Ficus bengalensis*
Canna	*Canna spp.*
Cassava	*Manihot esculenta* Crantz
Gliricidia	*Gliricidia maculata*
Hibiscus	*Hibiscus Rosa-sinensis*
Ipil-ipil	*Leucaena leucocephala*
Jackfruit	*Artocarpus heterophyllus*
Lantana	*Lantana spp.*
Passion fruit	*Passiflora edulis f. flarcarps*
Pigeon pea	*Cajanus cajan*
Singapore rhododendron	*Melastoma malabathricum*

3.6 Miscellaneous Non-conventional Feedstuffs

In addition to the various types of non-conventional feeds that have been discussed, there exist several other that have not been mentioned in this report simply because of want for more information. These include *inter alia* azolla from rice fields, cashew bran, cassaia taro seeds, coconut pith, karanj cake, mustard cake, safflower seed/cake, silk worm pupae meal, spent annatto seeds, sunhamp seeds, tobacco seed and cake, and animal excreta like cow manure. Castillo (1983) for example, has discussed the value of coconut leaf blades (laminae without midribs) and coconut petiole (main indrib) without the rind, as edible green feeds. Both components are usually chopped before feeding to ruminants. The list is infinite, and suggests that the potential value is dependent essentially an availability as well as knowledge an nutritive value. Efforts to do so are apparent from the limited studies that have been reported.

Patel, Patel and Talapada (1972) used 50% tomato waste or 40% mango kernels for feeding bulls and found this to be economic; no adverse effects were found on growth or N, P and Ca balance.

Yeast sludge has been used to replace some or all of the groundnut meal, sesame cake and rice bran in the basal diet equivalent to 0, 25.1, 56.3 and 81.7% of the total dietary protein for White Leghorn chicks. It was concluded that average live weight gain and feed efficiency to eight weeks was greatest with 18% yeast sludge (Singh and Sachan, 1972).

Patel, Shukla and Patel (1972) have evaluated the value of various pulse vines: *Phaseolus aureus*, *P. mungo* and *Dolichos lablabs*, and reported that the TDN contents were 57, 57 and 47% respectively for dry kankrej cows.

Dried beet pulp has been fed to Hariana heifers (Bhandari and Maheswari, 1972), and digestibility coefficients of 49.9% for dry matter, 42.1% for crude protein and 56.0% for crude fibre have been noted.

In Gujarat, India, seeds for watermelon (*Citrullus vulgaris*) when crushed for the extraction of oil, produces a by-products called watermelon cake. Feeding trials using up to 20% of this cake with two lactating Hariana calves indicated that this can be utilized by the animals (Sastry, Singh and Dutt, 1973).

Mustard cake has been used in diets for chicks and it has been reported that the ME content was lower than that of groundnut cake.

Penicillin mycelium residue has been used to substitute 50 and 100% of dietary fish meal, equivalent to 12 to 25% of the total diet in broiler chicks, and concluded that the mycelium residue could be used to replace about half dietary protein (Patel and Sayed, 1973). The inclusion of penicillin mycelium also reduced the cost of feeding.

Some work has also been done in feeding wastes of animal origin in livestock. Dried rumen digesta fed at 0, 10 and 15% levels in the diet of pigs gave no treatment differences (Reddy and Reddy, 1977). Feeding 5 to 15% sun-dried cows waste gave good growth rates in chickens (Dhillar, Sagor and Yadava, 1972). Waste silkworm pupae when fed to sheep as the sole concentrate, resulted in a positive N, Ca and P balance (Khan and Zubairy, 1971). Other miscellaenous wastes used in livestock feeding have been reviewed by Mueller (1979) and a practical guide to the utilization of animal wastes for various classes and species of animals has recently been published (Mueller, 1982).

3.7 Optimum Level Of Utilization

In the formulation of practical balanced diets for feeding individual farm animals, one immediate consideration is the technically optimum level of the feed which can be used to advantage. The question brings to bear the importance of the more fundamental aspects of research on the nutritive value of individual by-products, from chemical analysis, digestibility and balance studies to practical feeding trials that can relate optimum levels of individual by-products to feed efficiency and animal product output.

Table 23 brings together the available information from practical feeding trials where graded levels of 14 non-conventional feedstuffs were used. The identification of optimum levels was based on the results of these studies. Thus a 30% level of poultry excreta would appear to be optimal for ruminants and 5 - 10% for poultry. With oil palm by-products the optimum level of inclusion in ruminant diets is 30-40%. With rubber seed meal- the cooresponding level for all species of livestock in India, Malaysia and Sri Lanka appears to be 20%. In India, cows and bulls appear to tolerate an optimum level of 40% sal seed meal.

These optimal levels of inclusion represent an approximation of the amounts that are likely to promote good response in the animals. The levels will be influence, no doubt, by other ingredients in the diet and by the ability of individual species to utilize these materials. Thus goats appear able to lutilize coarse cellulosic material much better than sheep or cattle (Devendra, 1978d). The removal, of toxic or deleterious components is of course important in this context.

TABLE 23

OPTIMUM LEVEL OF UTILIZATION OF SOME IMPORTANT BY-PRODUCTS IN DIETS FOR FARM ANIMALS IN SOUTH EAST ASIA

Non-conventional feedstuffs	Animal Species	Location	Optious level of inclusion in the diet (%)	Reference
I. Animals				
1. Blood meal	Pigs	Malaysia	3	Hew and Devendra (1977)
2. Poultry excreta	Poultry	Malaysia	5 - 10	Ng and Hutagalung (1974)
	Poultry	India	15	Ann. Rpt. I.C.A.R. (1983)
	Sheep	Malaysia	20 - 30	Devendra (1976b)
	Cows	Thailand	30	Tinnimit (1977)
II. Plants				
3. Cocoa				
Cocoa pods husk	Sheep	Malaysia	30	Devendra (1977d)
4. Mango	Calves	India	20	Patel and Patel (1971)
Mango seed	Bullocks	India	40	Patel, Patel and Talapada (1972)
Kernel	Cows	India	10	Ann. Rpt. I.C.A.R. (1983)
5. Oil palm				
Palm oil mill effluent	Sheep	Malaysia	40	Devendra and Muthurajah (1976)
Palm press fibre	Sheep	Malaysia	30	Devendra and Muthurajah (1976)
Palm oil sludge*	Sheep	Malaysia	40	Devendra and Muthurajah (1976)
Palm press fibre	Pigs	Malaysia	10 - 15	Yeong (1981)
Palm oil solids	Poultry	Malaysia	10 - 15	Ong (1981)
6. Pineapple				
Pineapple bran	Poultry	Malaysia	15	Ng and Hutagalung (1974)
7. Rice				
Rice husk	Sheep	Malaysia	5	Devendra (1977c)
8. Rubber				
Rubber seed meal	Pigs	Malaysia	20	Ong and Yeong (1977)
	Poultry	Sri Lanka	20	Buvanandran and Siriwardene (1970)
	Poultry	Sri Lanka	20	Rajaguru (1973)
	Calves and Cows	India	20	Ann. Rpt., 1975-76)
	Calves	India	30	Ann. Rpt. I.C.A.R. (1983)
	Cows	India	25	Ann. Rpt., I.C.A.R. (1983)

Non-conventional feedstuffs	Animal Species	Location	Optious level of inclusion in the diet (%)	Reference
9. Sal				
Sal seed meal (untreated)	Poultry	India	5	Verma (1970)
Sal seed meal (treated)	Poultry	India	20	Sharma, Wah and Jackson (1977)
	Cows	India	30	Sonwana and Hudgal (1974)
	Bulls	India	40	Shukla and Talapada(1973)
	Pigs	India	40	Pathak and Ranjhan (1973)
10. Spent tea leaf	Calves	Sri Lanka	17	Jayasuriya (1978)
	Calves	India	20	Ann Rpt. I.C.A.R. (1983)
11. Sugarcane				
Bagasse (untreated)	Bullocks	Pakistan	10	Khan, Qazi and Schneider (1962)
Bagasse (treated)	Sheep	Malaysia	20-30	Devendra (1979b)
12. Sun hemp				
Sun hemp leaves	Poultry	India	8	Reddy, Rao and Subhan (1970)
13. Tamarind				
Tamarind seed hulls	Calves	India	10-15	Reddy, Reddy and Reddy (1979)
	Calves	India	25	Ann Rpt.I.C.A.R. (1983)
14. Water hyacinth				
Water hyacinth meal	Calves	India	10-20	Reddy and Reddy (1979)
15. Water melon				
Water melon cake	Calves	India	20	Sastry, Singh and Dutt (1973)

3.8 Conclusions On The Utilization Of NCFR

The above review on the current status of utilization of the various types of non-conventional feedstuffs enables six general conclusions to be drawn:

(a) The available data that most laboratories in the Region continue to use the Weende proximate analysis scheme. Very few laboratories use modern methods of chemical analyses for constituents which include *inter alia*: cell wall constituents or neutral detergent fibre, lignin, *in vitro* digestibility, alkaloids, tannins and other inhibitors.

(b) No precise quantitative information is available on NCFR.

(c) Most of the work done has been sporadic, uncoordinated, lacking in depth and thus unable to give precision to the value of individual feedstuffs for either ruminants or non-ruminants.

(d) What work has been done is evaluation-oriented with the basic objective of establishing acceptability and potential value.

(e) There exists only limited results from large scale feeding systems involving NCFR that can demonstrate high production from specific types of animals.

(f) There is an extreme paucity of information, consistent with (e), on profitability and economic viability.

4. ASSESSMENT OF BIOLOGICAL FEASIBILITY

The assessment of technical and biological feasibility of using many of the NCFR needs to be considered against the background of the various constraints that currently beset their more intensive utilization. Traditional feedstuffs such as maize, are well understood because of an enormous body of research that has gone into their efficient utilization and also because of considerable demonstrable results from numerous feeding trials. These considerations do not apply to NCFR for a variety of reasons which have already been discussed.

Nevertheless, an assessment must be made of biological feasibility of utilizing NCFR in animal feeding. It is considered that based on the currently available information on utilization of individual non-conventional NCFR in terms of primary and secondary feedstuffs as follows:

Primary feedstuffs - major ingredients that from the base in a feeding systems and

Secondary feedstuffs - minor ingredients that supplement the diet.

In either case, only the more important feedstuffs have been tabulated (Tables 24 and 25). This is to enable a manageable locus on potential utilization especially with respect to the major feedstuffs.

4.1 Primary NCFR From Major Crops

Of these major feedstuffs, the most important are those derived from cassava, cocoa, oil palm and sugarcane (Table 24). All these four crops have distinct biological feasibility for feeding animals and also environmental impact. A brief discussion on how the feedstuffs generated can be more intensively utilized is presented below.

TABLE 24

PRIMARY NON-CONVENTIONAL FEEDSTUFFS IN ASIA AND THE PACIFIC REGION

Origin	Feedstuffs
Cassava+	Cassava waste
Cocoa+	Cocoa pod husk
Ipil-ipil	Ipil-ipil forage
Jackfruit	Jackfruit leaves
Maize+	Maize stover
Oil palm+	Palm press fibre
Pigeon pea	Pigeon pea forage
Sago	Sago waste
Sugarcane+	Sugarcane tops
	Bagasse
Water hyacinth	Water hyacinth forage
Wheat	Wheat straw
	Wheat middlings

+ Major crops which are particularly significant in the Region

TABLE 25

SECONDARY NON-CONVENTIONAL FEEDSTUFFS IN ASIA AND THE PACIFIC REGION

	Origin	Feedstuff
I.	Animals	
1.	Poultry	Feather meal
		Poultry litter
		Poultry waste
2.	Ruminants	Blood meal
		Meat meal
II.	Plants	
3.	Banana	Banana waste
4.	Cassava	Cassava leaves
5.	Coffee	Coffee seed hulls
6.	Groundnut	Groundnut vines
7.	Guar	Guar meal
8.	Mango	Mango seed kernel
9.	Neem	Neem seed cake
10.	Oil Palm	Palm oil mill effluent
11.	Pineapple	Pineapple waste
12.	Rubber	Rubber seed meal
13.	Sal	Sal seed cake
14.	Tamarind	Tamarind seed hulls
		Tamarind seed cake

4.1.1 Cassava

Cassava is valuable crop that yields cassava chips, leaves and cassava waste from flour manufacture. The usefulness of cassava as an animal feed is well known, and its importance outside the Region is reflected by its use in countries belonging to the European Economic Commission (EEC) where about five million tonnes of cassava root meal are imported annually; over four million of this comes in pellet form from the Asian and Pacific region.

Cassava products and especially chips, can be used as substitutes for cereals in the diets of different species of farm animals in both tropical and temperate countries. The level of inclusion depends on the physical properties of the diets, their palatability and consumption.

More use can be made of cassava as an energy source for both non-ruminants and ruminants in the cassava-producing countries. Cassava can be used to produce single cell proteins. The processing technology has also highlighted a number of promising fields for further research on cassava.

4.1.2 Cocoa

The main by-product, cocoa pod husks, is likely to increase in the future. Because of its bulk, rapidity of fermentation and apparent value in feeding systems, the most appropriate use is to feed it in situ in areas where it is produced. In Malaysia, this is in the vicinity of the coconut areas where cocoa is currently an inter-crop. The use of cocoa pod husks in this nammer would facilitate further integration of crops with ruminants.

4.1.3 Maize

Maize stover is widely available, but no effective feeding system has been demonstrated that can stimulate its increased utilization. This is associated with problems of collection, possible processing and production in areas where there is no intensive system of ruminant production, particularly cattle production.

Two methods of feeding maize stover appear to be feasible in areas where substantial quantities are available. One is to chop the stover and feed it dry with molasses-urea and other supplements, as is done in the Philippines (see. 4.1.5). The other is silage making, of which very little is known in the Region.

4.1.4 Oil palm

The by-products from oil palm (palm press fibre and palm oil mill effluent) have a potential value that has not been adequately explored. The availability of these by-products is increasing (Table 8) which has the disadvantage that if they are unused, they would adversely affect the environment. Further research and development effort is required to increase their utilization.

When oil palm by-products constitute a major component of the diet (50% and above) the amount of dietary fat ingested is high and this leads to poor appetite caused by reduced rumen function. In some cases, there is also diarrhoea. A balance must therefore be found between an optimum level of these by-products and an adequate supply of other nutrients for good performance.

Alternative pathways should also be explored to consider incorporation of the palm oil sludge with other media such as cassava which by fermentation or biodegradation can increase the quality of the derived product. The use of suitable micro-organisms could be of value because of the additional advantage of reduced biological oxidation demand (B.O.D.) in the effluent. A successful example of this approach is the production of 'Prolima' which has the characteristics of soyabean meal. The product was produced by biodegrading the effluent using selected microorganisms and separation to improve the quality.

4.1.5 Sugarcane

Bagasse is a much neglected by-product of the sugar industry that merits more investigation with particular reference to its possible alternative economic uses viz. as an animal feed, as a source of fuel or in the manufacture of boards, or paper pulp.

4.2 Secondary NCFR From Minor Crops

The secondary NCFR which supplement the diet are of two categories: energy and protein sources. Of these, the protein sources are by far the most important since there is a general shortage of these, and also they are generally more expensive. Thus even small supplies of these are very valuable in furnishing the requirements that are essential for production. Notable in this regard, are such examples as feather meal, poultry litter and blood meal of animal origin, and cassava leaves, guar meal, neem seed cake, rubber seed meal, sal seed cake and sesame meal of plant origin (Table 25).

There is inadequate information on the amino acid profile of these protein sources and their effectiveness in diets that can give maximum response in animals. There is also a need for research that would help evaluate the quality of these various protein sources.

4.3 Economic Aspects Of Utilizing NCFR

The biological feasibility of utilizing NCFR for farm animals becomes more important if it can also be demonstrated that there is a reduced cost of feeding and production. Unfortunately however, there is a great dearth of information on this aspect, and this calls for the highest priority in research being directed at the economic usefulness of primary and secondary NCFR in feeding systems for both ruminants and non-ruminants.

The economic feasibility of utilizing some of the more important NCFR that have been identified (see. 5.1 and 5.2) is a subject that needs thorough investigations as part and parcel of an assessment of the nutritional properties, limitation if any and value within feeding systems. In general these facets have rarely been considered together in a research programme and therefore need attention.

Nevertheless, it is relevant to consider the oppottunities for such work using good examples of non-conventional feeds. The assessment can be considered for two particular situations:

4.3.1 situation where the particular by-product availability is substantial, and the opportunity exists for feeding the material directly _in situ_.

4.3.2 where opportunity exists for production of processed feed, whose inclusion in the diet has potential possibilities of reducing the cost of feeding.

4.4. Situation Where NCFR Can Be Fed In Situ

A good example of this, provided by a valuable study, is that of Dalzell, (1978). The work was done in an oil palm estate in south Malaysian with the objective of investigating the utilization the by-products of palm oil production as animal feeds, and as a means of pollution control. The project involved both buffaloes and cattle either grazed or intensively stall-fed over three year period. However, the economic evaluation was restricted to feed lot cattle.

The economics of the feed lot operation is as follows:

Capital Items	$ Malaysia*
Building-Feeding mixing storage office	30,000
Housing	54,000
Feed mixing equipment	55,500
Feed-lot construction	67,800
Vehicles & equipment	132,700
Total capital items	$ 340,000

Operating Costs	$ Malaysia*
1. Cattle purchases - 2,260 @ $238.50	539,000
2. Administration, salaries, wages	152,000
3. Feeding material purchases	5,700
4. Transport operating costs	12,000
5. Veterinary costs	13,000
6. Depreciation on capital items	25,000
Total annual costs	$ 746,700

Income	
Cattle sales	
2,260 less deaths @ 3%	
= 2,192 @ $ 505.00	$ 1,106,960
Income in excess of costs	$ 360,260

* 1 US$ = $2,20 Malaysian.

Assumptions are that:

1. the feed-lot is on an estate adjacent to the palm oil mill.
2. the palm oil mill has a capacity of 30 tonnes/hour.
3. land is considered to be free and also supplies of POS and PPF.
4. the feed-lot cattle numbers are sufficient for cunsumption of POS produced in the lowest production months, e.g. 2,000 tonnes of POS containing 90% moisture.
5. the POS could be processed to reduce the moisture content from 90 to 75% or lower.
6. the 2,260 cattle consuming 11.8 kg of POS content with 75% moisture (2.95 kg dry matter/head/day), would be fed on the montly production of 2,000 tonnes.
7. cattle would be purchased at 90 kg live weight and fed for 1 year giving a daily gain of 453 g.

Clearly, the utilization of these feedingstuffs *in situ* has very definite economic advantages, and can be pursued further.

4.5. Situation Where Processing Opportunities Exist For Feedstuffs That Can Reduce The Cost Of Feeding

The second example, concerns rubber seed meal. Provided the seeds can be collected, it is possible to process them into rubber seed meal, which as several studies have indicated (see 4.4.1), can be utilized for feeding ruminants in particular. The following calculations demonstrate the reduced costs of feeding resulting from the use of rubber seed meal.

Two experiments are cited, both involving rubber seed meal. In both examples, a 20-25% level of rubber seed meal partially replaced soyabean meal for either broiler or egg production and both diets were compared to control diets which did not have rubber seed meal. The control diets in both cases, as one will expect, were more expensive than those with rubber seed meal.

The studies indicated that for both situations, the average daily gain or percentage egg production, average egg mass and feed efficiency were comparable to the control diets. Since rubber seed meal is cheaper, the cost of production associated with its use for either meat or eggs was more economical than the more expensive control diet. The data below summarise the mean results of this comparison.

Diets (% composition)	(i) Broiler production (5th-10th week age) Control	Rubber seed meal	(ii) Egg production (mean of (50 weeks, 28th-77th weeks age) Control	Rubber seed meal
Maize	66	53	62	45
Soyabean meal	19	7	2222	8
Rubber seed meat	--	25	--	30
Fish meal	8	8	4	4
Leaf meal	2	2	2	2
Palm oil	3	3	--	1
$Ca_2(PO_4)_3$	1	1	1.6	1.5
Vit-minerals	0.75	0.75	1	1
Salt	0.25	0.25	0.4	0.4
Limestone powder	--	--	7	7
DL-methionine	--	--	--	0.1
Cost/100 kg (M$)	51.32	47.2	44.6	40.1
Average daily gain (g)	32.2	31.9	--	--
Feed efficiency	3.15	3.21	--	--
% Egg production	--	--	65.8	65.0
Average egg (kg)	--	--	12.6	12.3
Feed/gain in egg mass	--	--	2.7	3.0

Similar examples of this situation are not uncommon and are in fact evident in a number of studies throughout the Region. These examples apply to both energy and protein substitutes alike where the non-conventional feeds have replaced or partially substituted the traditional feed ingredient.

The real prospects for effective utilization of NCFR are associated with two principal factors:

(i) nutritive value

(ii) cost of collection, transportation and added costs of detoxification and processing that exceed the economic value relative to conventional raw materials.

Increasing the more intensive use of NCFR must clearly rest with overcoming the problems associated with the second factor. The major cost component in using NCFR is not the growing, but the harvesting, transporting and processing of the feedstuffs. Hand harvesting only appears to be economically feasible on small family farms (about 2 ha), however, the costs of collection and processing where necessary, need to be kept to a minimum. On the other hand, where both of these factors are not an immediate problem, and the opportunity exists for feeding in situ, new initiatives are necessary to encourage this development.

The nature and magnitude of the problems and potential prospects for economic utilization can only be realised by more vigorous research on a variety of aspects concerning NCFR. Attention should also therefore be given to total assessment, evaluation and utilization of the more important NCFR. Systematic studies are needed on the factors affecting the intake, digestibility and efficient utilization for animal product output. It is still too early to generalize about the economics of the use of individual non-conventional feeds in view of the current constraints, and also because much depends on the management system employed. Research towards more efficient utilization of NCFR will have the advantages of extending and alleviating the imbalance between total animal resources and feed supplies, and more particularly, support for increased productivity from the animal genetic resources as a whole.

4.6. Deleterious Components In NCFR

Many NCFR contain substances that are deleterious to animal health. Little is known about the affects of these to the animal body both in the short and long term. One is the presence of HCN or prussic acid in the "bitter" varieties of cassava leaves and stems and in rubber seeds. If these feedstuffs used without treatment, death may occur in extreme cases. Fortunately, methods are now available to detoxify the HCN. The level of dietary sulphur amino acids is an important factor influencing cyanide toxicity through formation of SCN^- from cyanide (Hill, 1977).

The second example concerns tannins which are widespread in such feedstuffs as sal seed cake, tamarind seed hulls, sorghum, leucaena and water hyacinth. Often a low digestibility of the feedstuffs and poor performance are attributed to tannins in the feed. However, there is no evidence that tannins in forages are harmful. The degree of toxicity is dependent on the type of tannins and also the tolerance between animal species. Ruminants can tolerate a much higher concentration of tannins than rats or chicks. They can inhibit the activity of microorganisms in the rumen and depress the digestion of protein and fibre (McLeod, 1974. On the other hand, tannins have been used to protect proteins from breakdown in the rumen (Driedger and Hartfield, 1977). With leucaena forage, there exists the toxic nonamino acid mimosine, which is degraded to another toxic compound, 3-hydroxy-4(1H)pyridone (DHP). The latter is goitrogenic. Other examples include the presence of theobromine caused by fermentation of cocoa pod husks (see section 4.2.1) and also a trypsin inhibitor in guar meal (see section 4.4.1). The limitations in NCFR including the presence of antimetabolites has recently been discussed (Devendra, 1985).

Clearly for both primary and secondary NCFR to be valuable and effectively utilized in feeding systems, all deleterious components must be removed by practical appropriate techniques in order that high performance in animals be ensured. D'Mello (1982) has recently discussed toxic factors in some tropical legumes.

4.7 Increasing Palatability By Inclusion of Molasses

One major problem associated with increasing the utilization of NCFR is that of poor palatability. Many of the feedstuffs have poor palatability and good example of this are cassava chips, palm oil mill effluent, sal seed meal, neem seed cake and tamarind seed hulls. In the raw form these feed ingredients are unlikely to have a significant effect on performance unless they are combined in suitable combination with other dietary ingredients that will ensure both good palatability and also maximum dry matter intake.

Notable in the ability of achieving both objectives is the value of dietary molasses, together with urea. Considering the content of soluble carbohydrates in molasses which can replace more expensive carbohydrates, the laxative properties of molasses, its sweetness and value as a carrier of a non-protein nitrogen (NPN) such as urea or biuret, it is a particularly valuable dietary ingredient. With many of these NCFR dietary molasses ensures an adequate intake and associated good response in the animal. Molasses can also be used in silage making. Most of the countries in the Region have access to molasses, although in some, the relative cost is high and may well preclude its use. Molasses is also a raw material for the production of alcohol, other fermentation products and finds minor uses in the tobacco industry.

4.8 The Significance Of Dietary Urea

The value of NPN sources like urea is associated with dietary molasses. Not enough use is being made of the value of dietary urea, mainly because of inadequate understanding of the principles of NPN used by the ruminant. Possibly the greatest value of urea is associated with three advantages. Firstly, preformed or true proteins are spared from inefficient breakdown and utilization by rumen micro-organisms. Secondly, these can be conserved for more efficient use in non-ruminant pig and poultry feeding and also for human use. Thirdly, NPN use generally reduces the cost of feeding.

Much greater use can be made of urea in the Region, especially for feeding ruminants. Many of the NCFR are excellent sources of soluble carbohydrates, their use in conjunction with urea will ensure that there will be maximum microbial protein synthesis.

Expanding the use of NPN sources like urea of biuret in the Region can be achieved by employing one of several methods appropriate to a particular situation. Some of the methods applicable are as follows:

(i) Spraying to pasture
(ii) Spraying or addition to hay
(iii) As a liquid in a trough in association with molasses
(iv) As a block lick
(v) Inclusion in drinking water
(vi) Additive in cereals or concentrates.

Recently, molasses-urea blocks have been extended to small farm situation in India and the Philippines because of their attractiveness and taste to livestock. More particularly, the blocks are a potentially effective means of making NPN such as urea (15-20%) continuously available, fortified with macro and micro minerals and other nutrients, essential to both the microbes and the animal. The possibility of over-ingestion of the block and the danger of toxicity appears to be remote (Leng and Preston, 1983).

5. PROPOSAL FOR A COORDINATED RESEARCH PROGRAMME

The consultant has stressed the need in the Report, for the highest priority in research being directed at the economic usefulness of primary and secondary NCFR in feeding systems for both ruminants and non-ruminants (see section 5.3). This assessment will also include description of these feeds, their characterisation, extraction rates, availability and nutritive value. In order to align research and development programmes to these objectives in countries of the Asian and Pacific region, a coordinated research programme is proposed.

5.1 Objectives

The objectives of the project are three fold:

1. Assess the availability and nutritional value of primary and secondary NCFR (Immediate).
2. Develop suitable feeding systems appropriate to individual species that can promote good performance.
3. Demonstrate economic usefulness (Long term).

5.2 Plan Of Work

The project will be carried out in three phases. The first phase, to last for one year, requires detailed national surveys to realised objectives one above. This can be carried out by individual institutions in each country. The second phase, to last 4 years, would be directed to a systematic assessment of the nutritional value of chosen NCFR, their limitations, value in feeding systems and economic usefulness. This phase of the work will be carried out at one or more centres in individual countries. focussing on gaps in current knowledge as immediate objectives and leading to the realization of effective and economic feeding systems in the long term. The third phase, lasting for two years, would be carried out on development farms for purposes of demonstrating the developed technology.

5.2.1 Phase One

The proposed survey is aimed at identifying primary and secondary NCFR in individual countries in the Region. This serves to decide at the outset what types of feedstuffs and animals are involved and the scale of the oepration. This assessment calls for a detailed survey on the availability of NCFR. Arising from this survey, it should be possible to focus attention on selected non-conventional feedstuffs (see section 5.1 and 5.2) for purposes of making a thorough assessment of the nutritional properties of the feedstuffs.

5.2.2 Phase Two

This phase will be concerned with the usefulness of selected feedstuffs in feeding systems for ruminants and non-ruminants. Attention should be directed in the long term at how best these feedstuffs can be incorporated in diets to achieve maximum response from farm animals commensurate with reduced cost of feeding compared to control diets. The choice of feedstuffs and suitable animals for the experiments will obviously vary from country to country and in relation to national priorities. It is recommended however, that attention should be focussed on those feedingstuffs that have been identified in tables 24 and 25.

In order to achieve this, the following approach is suggested as a guide:

	Country	Feedstuffs to be concerned with
1.	India	Guar meal, neem seed cake, sal seed cake, tamarind seed cake, and tree leaves.
2.	Indonesia	Leaves of field and tree crops.
3.	Pakistan	Sugarcane by-products and tree leaves.
4.	Philippines	Ipil-ipil, pineapple and banana wastes.
5.	Malaysia	Cocoa and oil palm by-products.
6.	Sri Lanka	Rubber seed meal.
7.	Thailand	Cassava.

The final aim of this phase is to demonstrate effective and economic feeding systems involving the NCFR.

5.2.3 Phase Three

This phase will be concerned with development effort. It is best done at the village level in selected experimental sites which can involve the farmers. In these centres, the developed technology will be taught by hired technicians to farmers according to the experimental plan. The farmers will be expected to mix and weigh the feeds offered and refused, weigh the animals and milk produced and also maintain records on the performance of the animals. The feed ingredients will be supplied free of cost to the participating farmers for two reasons. Firstly, most farmers do not have ready cash to purchase feedstuffs. Secondly, such a provision will motivate the farmers to continue using non-conventional feedstuffs long after the project is over. It is desirable therefore that this provision be made by participating institutions concerned with livestock development programmes in individual countries.

5.3 Participating Institutions

The following institutions are recommended for participation in this project:

1.	India	1) Indian Vet. Res. Institute (Izatnagar).
		2) National Dairy Research Institute (Karnal).
2.	Indonesia	Directorate of Animal Husbandry.
3.	Pakistan	1) Agricultural University, Faisalabad.
		2) Livestock Division, Ministry of Food and Agriculture.
4.	Philippines	1) University of Philippines, Los Banos.
		2) Bureau of Animal Industry.
5.	Malaysia	1) Malaysian Agricultural Research and Development Institute.
		2) Veterinary Division, Ministry of Agriculture
6.	Sri Lanka	University of Sri Lanka, Peradeniya.
7.	Thailand	1) Khon Kaen University, Khon Kaen.
		2) Department of Livestock Development.

5.4 Workshops

It is important to stimulate interest in, and disseminate knowledge on, the effective utilization of NCFR between various individuals and institutions in the Region. This can be achieved by holding Workshops once every two years in each of the participating countries in rotation. The Workshops will enable the scientists to meat, discuss and also visit ongoing research projects in that country and encourage a free flow of information.

5.5 Coordination

The initiation of this programme and the coordination of the entire project rests with FAO/APHCA.

6. RECOMMENDATIONS

Inview of the availability of non-conventional feed resources (NCFR) in considerable quantities in the South East Asian Region, and the biological justification for increasing their utilization, there should be a detailed national survey in individual countries of the types and amounts generated. This is a necessary pre-requisite for identifying the potentially more important types, availability, current patterns of utilization and marketing so as to initiate their development.

Since the NCFR are diverse and variable in quantity, priority should be given to the more important primary and secondary feedstuffs that have a high potential. Concerning the former, it is suggested that priority be attached to four major crops: cassava, cocos, oil palm, and sugarcane. With respect to the second category, attention should be directed at an assessment of a range of potentially important protein sources such as cassava leaves, rubber seed meal, sal seed cake and neem seed cake.

Attention to both these categories of feedstuffs call for the highest priority in research being directed to their economic usefulness for incorporation in suitable feeding systems plus descriptions of these feeds, their characterisation, extraction rates, availability and nutritive value.

Chemical analyses of NCFR feedstuffs using the proximate analysis scheme should be discontinued, and replaced by more modern methods which enable the determination of cell wall constituents, lignin, *in vitro* digestibility and inhibitory substances.

Special attention should also be directed where appropriate, to the nature and extent of various active priciples such as HCN and tannins in non-conventional feedstuffs that cause deleterious effects in animals. Studies are also needed on effective ways of eliminating the active principles and alleviating any effects on the animal. Much wider use can be made of NFN substances like urea, and this needs to be encouraged.

The value of developing individual non-conventional feedstuffs, free of any deleterious effects, should have the final aim of demonstrating effectiveness in feeding systems that are consistent with technical and economic feasibility.

Increasing information on various aspects of these non-conventional feed resources can result from well planned national and regional surveys, well coordinated research and development projects, improve linkages between institutions and personnel engaged in this types of work and dissemination of pertinent information.

Aproposal for a coordinated research programme has been made which addresses itself to more intensive research and development of NCFR in the Asian and Far East region. The objectives of this project are three fold: assess the availability and nutritional value of primary and secondary non-conventional feedstuffs (immediate), develop suitable feeding systems appropriate to individual species that can promote good performance and demonstrate economic usefulness (long term).

The initiation of this programme and the coordination of the entire project rests with FAO/APHCA.

7. ACKNOWLEDGEMENT

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APPENDIX I

THE CHEMICAL COMPOSITION OF SOME OF THE MORE IMPORTANT NON-CONVENTIONAL FEEDSTUFFS IN ASIA AND THE PACIFIC (% DM basis)

Feedstuff	Chemical composition									Reference
	DM	CP	CF	EE	Ash	MFE	Ca	P	GE (MJ/kg)	
1. Bulky by-products										
Banana waste	90.7	3.3	5.2	3.1	4.4	84.4	--	--	--	Castillo and Gorpacio (1976)
Banana item	5.3	0.2	1.5	--	1.1	--	--	--	--	Castillo (1983)
Cassava waste	90.0	1.8	5.0	0.2	8.0	85.0	0.12	0.15	14.94	Devendra (1979b)
Cocoa bean meal	91.8	20.4	8.1	9.8	3.8	57.9	--	--	15.31	Devendra (1979b)
Cocoa pod husk	90.4	6.0	31.5	0.9	16.4	45.2	0.35	0.09	--	Devendra (1979b)
Coffee hulls	--	10.0	40.6	0.9	7.4	41.1	0.40	0.15	--	Ranjhan and Khora (1976)
Coupta vines	11.1	16.6	24.3	1.8	14.4	42.9	2.90	0.72	13.97	Devendra (1979b)
Guar meal	--	43.0	7.1	3.8	6.8	39.3	0.16	0.70	--	Ranjhan (1977)
Jhanji	78.0	15.0	27.1	1.6	20.0	36.3	2.39	0.19	--	Gupta and Saha (1977)
Mango seed kernel	--	5.4	1.4	10.2	2.3	79.7	0.29	0.27	--	Sen and Ray (1971)
Maize stover	89.2	6.1	36.8	1.5	8.5	46.9	0.30	0.20	--	Devendra (1979b)
Neem seed cake	91.8	15.2	21.9	5.8	14.9	42.2	--	--	--	Bedi, Vijian and Ranjhan (1975)
Palm kernel cake	90.6	19.0	16.0	2.0	4.2	58.8	0.23	0.31	18.07	Devendra (1979b)
Palm press fibre	86.2	4.0	36.4	21.0	9.0	23.6	0.30	0.13	17.61	Devendra (1979b)
Palm oil mill effluent	90.0	10.6	18.3	17.0	12.1	42.0	0.75	0.50	17.66	Devendra (1979b)
Pineapple bran	87.4	4.8	25.5	1.9	4.5	63.3	0.29	0.24	13.43	Devendra (1979b)

(Continued)

Feedstuff	Chemical composition DM	CP	CF	EE	Ash	NFE	Ca	P	GE (MJ/kg)	Reference
Ragi straw	--	3.6	38.9	1.5	9.6	45.4	--	--	--	Sen and Ray (1971)
Rain tree pods	--	15.9	11.8	1.5	3.8	67.0	--	--	--	Kunju (1983)
Rice broken	98.6	7.5	7.0	1.1	5.0	79.4	0.32	0.34	--	Devendra (1979b)
Sago refuse	26.0	1.9	6.0	0.4	3.0	88.7	0.05	0.04	13.06	Devendra (1979b)
Sal seed meal	--	9.2	2.4	1.0	3.6	83.8	0.12	0.19	--	Ranjhan (1977)
Sugarcane bagase	95.3	2.7	37.4	0.3	5.7	53.9	0.11	0.31	13.31	Devendra (1979b)
Sugarcane tops	--	3.8	50.8	1.8	4.9	51.5	0.18	0.02	20.15	Devendra (1983a)
Sun hemp hay	--	25.0	31.6	2.8	13.0	27.6	1.47	0.36	--	Balaraman and Verkatakrishnam (1974)
Tomato pomace	--	22.3	26.3	10.2	6.5	34.7	--	--	--	Jayal and Johri (1976)
2. Leaves										
Bamboo (Hay)	87.7	12.0	27.0	0.8	18.0	42.2	0.19	0.13	--	Castillo and Gorpacio (1976)
Banana	27.1	16.1	23.7	8.4	9.4	42.4	--	--	--	Devendra (1979b)
Canna	11.5	11.4	25.6	3.2	10.1	49.7	--	--	15.19	Devendra (1979b)
Cassava	21.7	22.6	8.1	2.9	6.0	60.4	0.98	0.20	8.45	Devendra (1979b)
Glinicidia	25.0	14.7	19.9	5.4	4.7	55.3	0.46	0.14	23.08	Devendra (1983b)
Jackfruit	36.6	14.0	22.1	3.8	11.5	48.5	--	--	6.53	Devendra (1979b)
Leucaena (Philippines)	52.6	12.6	5.4	1.6	2.2	78.2	0.37	0.07	--	Castillo and Gerpacio (1976)
Leucaena leaves (Malaysia)	30.0	22.0	19.6	6.9	4.4	47.2	0.55	0.13	22.18	Devendra (1983b)
Leucaena leaves + stems + pods (Malaysia)	30.1	17.4	30.5	3.8	4.6	43.6	0.30	0.14	32.59	Devendra (1983b)

(Continued)

Feedstuff	Chemical composition									Reference
	DM	CP	CF	EE	Ash	NFE	Ca	P	GE (MJ/kg)	
Lantana	13.3	27.8	10.9	2.0	5.5	53.8	0.80	0.15	14.10	Devendra (1979b)
Mulberry	--	15.0	15.3	7.4	14.3	48.0	2.42	0.42	--	Ranjhan and Khere (1976)
Sesbania	85.6	22.6	18.4	2.1	9.3	47.6	1.10	0.32	--	Devendra (1979b)
Singapore Rhododendron	35.5	10.8	24.7	2.8	7.8	53.9	1.44	0.19	10.54	Devendra (1979b)
Sugarcane green tops	26.0	6.4	33.9	1.7	7.6	50.4	--	--	17.36	Devendra (1979b)
Tea waste	--	28.0	18.0	3.0	6.0	45.0	--	--	--	Kunju (1983)
Water hyacinth	14.7	12.1	22.5	1.7	13.3	50.4	1.62	0.50	10.38	Devendra (1979b)
3. Legumes										
Centrosema pubescens	24.3	22.2	30.9	2.5	9.5	34.9	0.78	0.45	15.15	Devendra (1979b)
Sesame meal	91.9	38.5	7.8	14.7	12.6	26.8	2.44	1.29	17.66	Devendra (1979b)
4. Miscellangous										
Banana whole plant	18.5	3.7	28.0	3.6	17.8	46.9	1.22	0.12	--	Gupta *et al*. (1976)
Feather meal	91.9	88.5	1.6	2.3	5.6	2.0	0.26	0.20	--	Devendra (1979b)
Groundnut leaves and stem	17.6	19.9	34.5	4.8	9.9	30.9	--	--	14.22	Devendra (1979b)
Poultry litter	36.0	24.2	25.4	2.1	18.1	30.2	--	--	15.48	Devendra (1979b)
Rubber seed meal	89.0	33.6	3.5	11.2	4.7	47.0	0.13	0.50	14.69	Devendra (1979b)
Tamrind seed hulls	--	9.1	11.3	0.6	3.5	75.5	0.26	0.76	--	Reddy, Reddy and Reddy (1979)
Tobacco seed/cake	--	29.9	22.3	10.3	12.7	24.7	--	--	--	Kunju (1983)

APPENDIX 2

TABLE 1

APPARENT DIGESTIBILITY OF THE MAIN PROXIMATE COMPONENTS IN DIETS WITH GRADED LEVELS OF RICE HUSK (%)

(Each value is the mean of four sheep)

(Devendra, 1977c)

Parameter	% Inclusion of rice husk						L.S.D.*
	5	10	15	20	25	30	(P=0.05)
Dry matter	91.7	81.8	74.7	68.6	62.6	54.7	2.4
Organic matter	93.1	85.3	79.3	74.6	69.2	67.5	6.0
Crude protein	80.6	67.2	56.2	57.7	45.1	55.3	7.4
Crude fibre	53.1	26.6	23.3	16.7	10.7	11.9	14.8
Ash	83.5	61.3	46.1	41.6	34.0	23.9	23.7
Nitrogen-free extract	97.3	93.2	91.8	88.6	86.5	78.3	4.2
Energy	89.3	77.6	69.1	63.4	55.1	54.9	8.3
N retention as % of intake (%)	66.4	51.1	36.2	32.4	25.8	26.7	11.8

* Least significant differences.

TABLE 2

APPARENT DIGESTIBILITY COEFFICIENT OF 4% NaOH TREATED BAGASSE BY SHEEP (%)

(Each value is the mean of 3 sheep)

(Devendra, 1979b)

Constituent	Treatments (% bagasse inclusion)								L.S.D.*
	5	10	15	20	25	30	35	40	(P/0.05)
Dry matter	83.6	80.4	78.8	77.6	76.9	74.0	72.7	73.3	4.2
Organic matter	85.5	82.0	81.1	79.5	78.2	75.6	72.9	73.8	4.1
Crude protein (N x 6.25)	82.0	78.1	82.6	72.9	82.8	80.5	73.4	71.4	N.S.
Crude fibre	78.7	80.9	78.2	73.3	75.8	73.8	64.7	43.3	11.9
Ether extract	58.6	59.8	64.6	58.9	58.4	62.7	53.0	57.9	N.S.
Ash	68.9	67.1	57.3	60.7	60.2	56.8	74.5	67.1	N.S.
Nitrogen-feee extract	87.6	83.3	81.3	82.0	77.8	75.0	75.2	79.4	N.S.
Energy	86.3	84.7	82.3	81.6	78.5	76.7	71.1	72.8	N.S.

* Least significant difference.

TABLE 3

APPARENT DIGESTIBILITY OF THE MAIN PROXIMATE COMPONENTS IN DIETS WITH GRADED LEVELS OF COCOA POD HUSKS (%)

(Each value is the mean of four sheep)

(Devendra, 1977d)

Constituent	% Inclusion of cocoa pods husks						L.S.D.*
	0	10	20	30	40	50	(P=0.05)
Dry matter	73.1	62.6	59.4	57.9	48.6	49.2	6.4
Organic matter	74.2	63.7	63.4	58.2	49.2	54.4	6.7
Crude protein	67.6	54.9	51.5	56.5	51.5	50.8	6.7
Crude fibre	28.1	27.2	29.0	32.6	30.5	23.1	11.2
Ether extract	70.4	57.2	56.7	59.6	80.1	75.2	14.6
Ash	74.7	68.6	68.1	76.2	62.0	58.0	13.4
Nitrogen-free extract	75.4	76.5	71.9	65.2	55.3	62.2	6.0
Energy	80.2	67.3	65.6	62.3	51.4	30.5	8.2
N retention as % of intake (%)	44.4	31.8	21.8	30.6	22.1	12.4	3.3

* Least significant difference.

TABLE 4

APPARENT DIGESTIBILITY OF THE MAIN PROXIMATE COMPONENTS IN DIETS WITH GRADED LEVELS OF PALM PRESS FIBRE (%)

(Each value is the mean of four sheep)

(Devendra and Muthurajah, 1976)

Constituent	% Inclusion of palm press fibre						L.S.D.*
	10	20	30	40	50	60	(P=0.05)
Dry matter	83.2	72.0	60.6	54.8	51.0	51.8	13.96
Organic matter	84.2	73.4	66.7	58.4	52.4	53.7	19.31
Crude protein	70.4	51.2	55.0	67.2	46.3	43.6	11.90
Crude fibre	75.4	50.5	51.2	39.6	37.5	36.3	29.81
Ash	64.9	65.5	51.1	45.0	25.4	27.7	19.74
Ether extract	80.4	81.2	94.3	95.4	92.6	93.1	5.72
Nitrogen-free extract	92.5	93.3	82.6	70.4	71.3	93.1	9.89
Energy	78.9	63.7	53.0	50.0	31.7	32.7	9.62
N retention as % of intake (%)	72.3	51.0	55.9	67.1	46.2	38.4	21.54

* Least significant difference.

TABLE 5

APPARENT DIGESTIBILITY OF THE MAIN PROXIMATE COMPONENTS IN DIETS WITH GRADED LEVELS OF PALM OIL SLUDGE+(%)

(Each value is the mean of four sheep)

(Devendra and Muthurajah, 1976)

Constituent	% Inclusion of palm oil sludge						L.S.D.* (P=0.05)
	10	20	30	40	50	60	
Dry matter	86.9	79.2	76.7	77.9	70.2	70.7	6.62
Organic matter	89.7	84.0	79.2	78.1	72.4	72.6	7.71
Crude protein	83.6	68.4	57.3	72.7	65.5	62.7	14.44
Crude fibre	80.6	40.2	34.0	21.1	30.3	27.0	23.29
Ash	57.8	43.0	46.1	34.2	57.4	27.9	N.S.
Ether extract	86.1	84.2	85.3	84.2	79.2	59.7	11.20
Nitrogen-free extract	90.7	73.6	69.9	69.5	64.4	70.4	21.30
Energy	84.5	77.5	63.5	74.9	72.9	76.3	7.81
N retention as % of intake (%)	83.3	68.3	57.3	72.7	62.8	62.6	14.86

\+ Now referred to as Palm oil mill effluent.
* Least significant difference.

TABLE 6

APPARENT DIGESTIBILITY OF THE MAIN PROXIMATE COMPONENTS
IN DIETS WITH GRADED LEVELS OF PALM PRESS FIBRE PLUS PALM OIL SLUDGE+(%)

(Each value is the mean of four sheep)

(Devendra and Muthurajah, 1976)

Constituent	% Inclusion of palm press fibre + palm oil sludge						L.S.D.*
	10	20	30	40	50	60	(P=0.05)
Dry matter	66.0	65.2	66.4	77.0	55.6	55.4	6.58
Organic matter	67.1	68.8	71.0	78.8	62.8	63.0	5.07
Crude protein	39.3	47.4	52.3	71.1	41.4	51.9	9.87
Crude fibre	28.5	33.8	39.5	68.5	34.1	54.3	15.15
Ash	82.8	57.5	57.2	35.3	12.8	21.1	34.21
Ether extract	86.9	88.7	92.6	98.0	97.7	97.8	4.70
Nitrogen-free extract	75.0	76.3	77.7	66.0	68.0	63.5	4.61
Energy	76.3	63.0	73.7	70.0	50.8	45.2	10.21
N retention as % of intake (%)	39.3	47.3	52.2	71.1	41.5	51.9	9.95

\+ Now referred to as Palm oil mill effluent.

* Least significant difference.

TABLE 7

APPARENT DIGESTIBILITY COEFFICIENTS OF PROXIMATE CONSTITUENTS IN TAMARIND SEED BY CATTLE IN INDIA (%)

(Rangneker, 1978)

Crude Protein	Crude Fibre	Ether Extract	Nitrogen free extract	Nitrogen balance (g/day)
63.5	69.6	54.7	63.1	+ 12.7

TABLE 8

APPARENT DIGESTIBILITY OF THE MAIN PROXIMATE COMPONENTS IN DIETS WITH GRADED LEVELS OF POULTRY EXCRETA %

(Each value is the mean of 4 sheep)

(Devendra, 1976b)

Parameter	% Inclusion of poultry excreta					L.S.D.*
	0	10	20	30	40	(P=0.05)
Dry matter	82.4	80.0	74.6	71.4	68.7	8.5
Organic matter	85.1	80.9	74.9	71.9	69.0	8.4
Crude protein	83.3	77.4	69.5	60.3	54.6	10.5
Crude fibre	69.4	52.7	58.4	62.1	64.7	--
Ash	86.5	80.8	74.7	70.6	55.7	10.8
Nitrogen-free extract	87.6	84.9	81.1	77.6	75.9	7.2

* Least significant difference.

TABLE 9

APPARENT DIGESTIBILITY OF CASSAVA LEAVES

(Each value is the mean of four sheep)

(Devendra, 1978c)

Constituent	Digestibility %
Dry matter	49.7
Organic matter	50.0
Crude protein	62.6
Crude fibre	50.3
Ether extract	6.8
Ash	45.8
Nitrogen-free extract	53.4
Energy	48.7
N balance*	62.5
Ca balance*	-ve-
P balance*	-ve-
Mg balance*	76.7

* As % of intake.

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